MECHANICAL DRAFTING

MILLER

Mechanical Drafting

REVISED IN 1915

By

THE DEPARTMENT OF GENERAL ENGINEERING DRAWING

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PREFACE

In writing the original edition of this text it seemed wise to the author to base its arrangement and content upon two principles which considerable experience proved sound. These principles are: first, that the student can just as well and perhaps better, be taught the use of instruments on work that will at the same time have educational value; second, that for greatest efficiency in teaching drawing the text should be made so complete and follow the class room work so closely that lecturing is unnecessary.

The above principles were followed by first designing a very flexible course in drafting, substituting drawings of machine parts for the conventional geometrical figures. The work was arranged into definite groups, according to subject, each group being scheduled for a definite amount of time. Second, the text was so arranged that section, lesson or chapter one, gave all information necessary for the work included in group one, etc.

After three years' very satisfactory trial of the text, the department of drawing has undertaken a complete revision with the desire that the work shall be not only a text, more complete than the first, but also a book of reference that will be of service after the student has completed the course.

H. W. Miller.

October, 1915.

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MECHANICAL DRAFTING

CHAPTER 1

LETTERING

FREEHAND

(1) Freehand or offhand lettering is so much a part of every engineer's daily routine that to be unable to letter with speed and grace is considered an inexcusable discredit. The results of practice show that no one need be embarrassed long because of the lack of this skill, for anyone can learn to letter. However, the acquisition of proficiency demands what skill in any manual performance requires,—more or less experience and careful study of principles.

It is fortunate for the beginner in lettering that there are very few elements that must be mastered. Most engineers use extremely simplified styles of freehand letters. The **Reinhardt** alphabet (*slant or vertical*) is especially noted for its simplicity as it has been stripped of all superfluous appendages that made formed styles both complicated and time-consuming in their use. In the practice of either type the beginner will find that all of the letters are made up of but two or three characteristic elements or strokes, each of which is easily constructed.

The first style or type presented is the Reinhardt *slant*. It should be mastered thoroly because it is in use in most drafting rooms and colleges. It is probable that its use in over eighty per cent of the large drafting rooms of the country is due to its legibility and ease and rapidity of construction.

EQUIPMENT

(2) **Selection of Lettering Pens.** For a pure type of either Reinhardt or vertical letter, such a pen should be used as will give a stroke of *uniform width, weight,* or *heaviness,* when it is moved *up, down, right, left,* or *diagonally* on the paper; otherwise the letter will have a shading, which does not belong to the types mentioned.

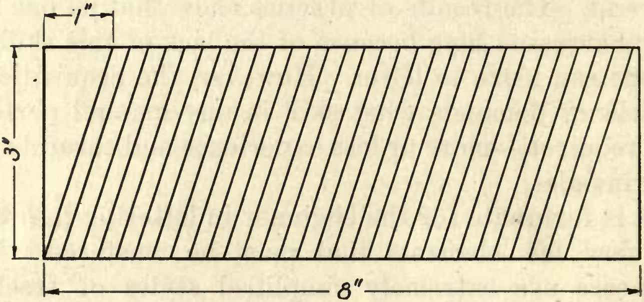


Fig. 1

Some pens which have proven satisfactory for letters of a uniform weight are the **Sheppard** lettering pen, **Paysant** pen, **Moore's Non-Leaking fountain** pen, and any of the steel points known as **ball pointed** pens.

Inking of Pens. Apparently a great part of the trouble experienced in the use of the above pens is due to improper inking. *No lettering pen should ever be dipped into the ink bottle.* The proper method is to *transfer* by means of the *quill* attached to the cork a small amount of ink to the *inside* of the ball pointed pen or *between* the nibs of the Sheppard or Paysant pens.

It is well to hold the pen point over the bottle so that any superfluous ink may not be spilled on the drawing or desk. The word of warning that must be heeded is to use *only enough* ink and no more. One may be sure of not having too much ink on the ball pointed pen if he will always stroke off the pen upon the quill before trying any letters.

Slope Guide. Immediately on beginning practice on inclined freehand letters it will be well to provide oneself with a sheet of heavy drawing paper, about *three* by *eight* inches, across which have been ruled a series of heavy *parallel* lines at from *70°* to *75°* to the *long edge* as shown in Fig. 1. These lines should be at equal intervals and from *one-eighth* to *one-quarter* inch apart. An angle of approximately **72°** may easily be constructed by laying off a *right triangle* whose *base* is *2* and *altitude 6,* Fig. 2. If this sheet, which may be termed a **slope guide**, be laid just below the line on which the freehand letters are to be made, it will not be difficult to make all first element strokes parallel to each other. It is likewise well to make use of such a guide continually until this slope has become perfectly natural, for *nothing so detracts from the good appearance of inclined letters as a difference in slope of the stems.*

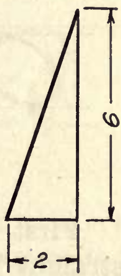


Fig. 2

Paper. A good quality of *ledger* paper will be found best for lettering, inasmuch as it has a smooth, hard surface that takes ink evenly. It is likewise well to adopt a standard letter size sheet, 8½x11, which will be found in stock in any printing office or stationery store, and to which all modern office files are adapted in case one wishes to file the finished work.

PRACTICE ON ELEMENTS

(3) **Guide Lines.** Unless especially printed practice sheets have been prepared, the beginner should rule on the blank sheet a series of six light parallel pencil lines (preferably parallel to the short edge of the sheet) at intervals of one inch and six at intervals of one-half inch.

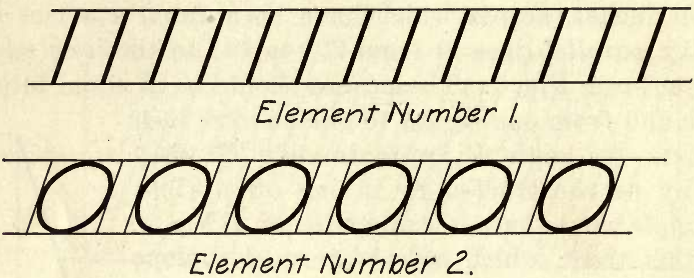


Fig. 3

First element, Stems. *Element one* is simply a **straight line** of varying length, Fig. 3, and making an *angle* with the *vertical* equal to the *slope* adopted for the inclined alphabet. In practice this slope can easily be secured by placing the slope guide just *beneath* the *guide line* on which one is working. Several lines of stems should be made on the practice sheet, using the half-inch guide lines, each with a *single downward stroke* of the pen and at *equal* intervals. When finished the stems should all have the *same slope*, be *evenly spaced* and each have the *same weight* or *thickness* thruout its length and *all stems* of the *same weight*.

Second element, Ovals. The *second element* is a **perfect ellipse,** inscribed in a parallelogram, *two* of whose *sides* are *parallel* to *element one* and whose *base* is, for normal letters, a little *less* than the *vertical height,* Fig. 3. This element can be made with one stroke of the pen, after some little practice; however, it is advisable for the *beginner* to form it with *two strokes,* as shown in Fig. 4, making slightly more than *half* each time and letting the ends of the strokes overlap. This will in general insure a better joint, as the overlapping tends to smooth out the juncture.

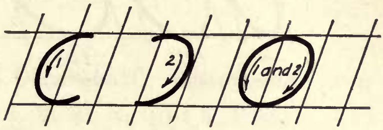


Fig. 4

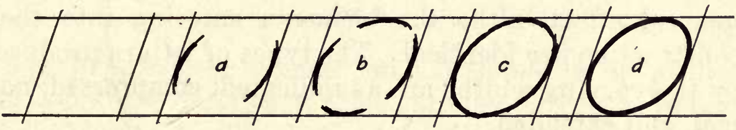


Fig. 5

In order that one may learn the shape of element number two in the least possible time, it is suggested that a beginning be made as shown in Fig. 5, with the height of the character one inch. Using the one-inch spaced guide lines already on the practice sheet, rule a series of *parallelograms,* bases *one* inch and *sides inclined* at the *slope angle.* Then sketch in long sweeping *arcs tangent* to the *inclined sides* at their *middle points,* a, Fig. 5; next follow the arcs tangent to the horizontal sides, b, Fig. 5. The completed shape now suggests itself, c, Fig. 5, and a few smoothing up strokes will complete the ellipse, d, Fig. 5. It should be remembered that the *ellipse* is *tangent* to the *sides* of the *parallelogram* at their *middle points;* this gives the necessary tip that is essential to a graceful appearance of the alphabet.

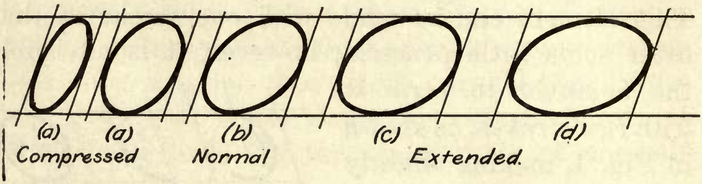


Fig. 6

An excellent variation of this exercise is that of making ellipses of varying widths. It is evident, Fig. 6, that this process will yield alphabets of widely differing general effect, altho the elements entering into their construction are identical. The types of letters produced by the varying widths are as indicated, **compressed, normal,** and **extended.**

The sketch exercise just outlined should be repeated with diminishing heights of *three-fourths, one-half, one-fourth,* and finally *one-eighth* of an inch, the size ordinarily used in drafting.

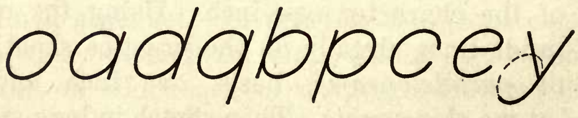


Fig. 7

FORMATION OF LETTERS

(4) In Fig. 7 it is seen that the lower case letters **o, a, d, q, b, p, c, e,** and **y,** and capitals **C, G, O, Q,** Fig. 10, are simple *elements* or combinations of *elements one* and

two. Element one and a portion of *element two* make up lower case letters **g, y, j, f, n, h, m, r, s,** and **u,** Fig. 8, and

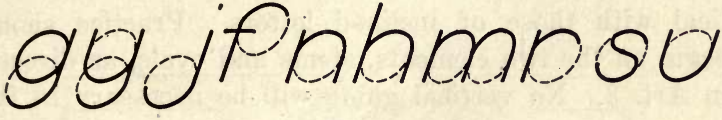


Fig. 8

capitals **B, D, J, P, R, S,** and **U,** Fig. 10. The remaining straight stroke letters, **i, k, l, t, v, w, x,** and **z,** Fig. 9, and **A, E, F, H, I, K, L, M, N, T, V, W, X, Y,** and **Z,** Fig. 10,

Fig. 9

are perhaps easiest to construct. It should be noted that the lower case letters **a, c, e,** etc., are two-thirds the height of the capitals. The letter **t** is five-sixths height and

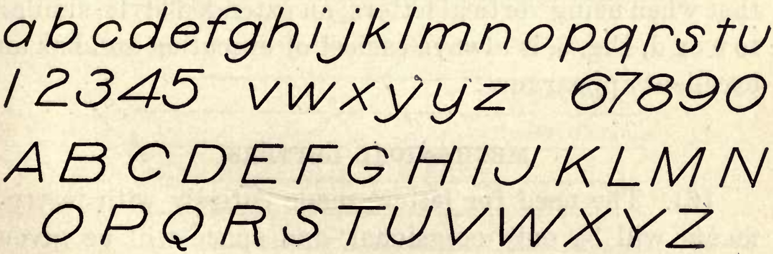


Fig. 10

b, d, h, etc., are full height. The tails of the letters **g, j, p, q,** etc., extend below the base line one-third their height. Numerals are the full stem height except when used in fractions when they should be shortened slightly. See Fig. 10 for complete slant alphabet and numerals.

VERTICAL LETTERS

(5) In Fig. 11 is given an alphabet of vertical letters. The principles of construction are of course identical with those of inclined letters. Practice should begin on the two elements, stems and ovals, as directed in Art. 3. No vertical guide will be necessary in this

Fig. 11

case, inasmuch as everyone has a well developed sense of appreciation of the vertical. It may be well to mention that when using vertical letters, an extended style, similar to c or d, Fig. 6, is always easiest of execution and has an excellent appearance.

MECHANICAL LETTERS

(6) The need for letters made entirely with instruments will be only occasional, and space will be given here for only the general methods for laying out such work. In the appendix will be found alphabets of various styles for use in the construction of titles, signs, name plates, etc. These may be constructed either mechanically or freehand, as desired.

Unit Space. If any given height which may be assigned to a letter be divided into *six* equal parts (for methods see Fig. 12) each of these parts is termed a

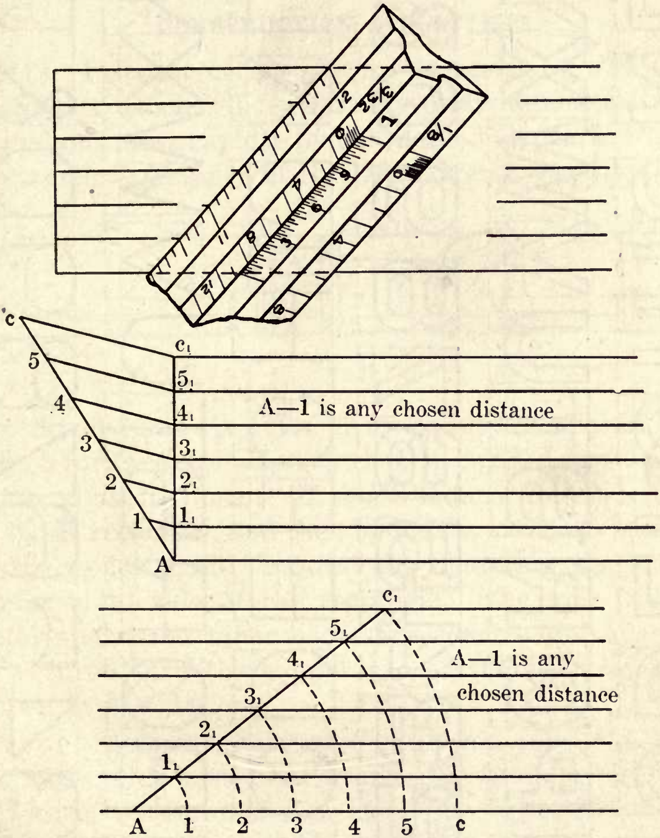


Fig. 12

unit space. It will be noticed in Fig. 13, which is of the mechanical vertical Gothic alphabet most commonly used by engineers, that all stems are of equal width, that is,

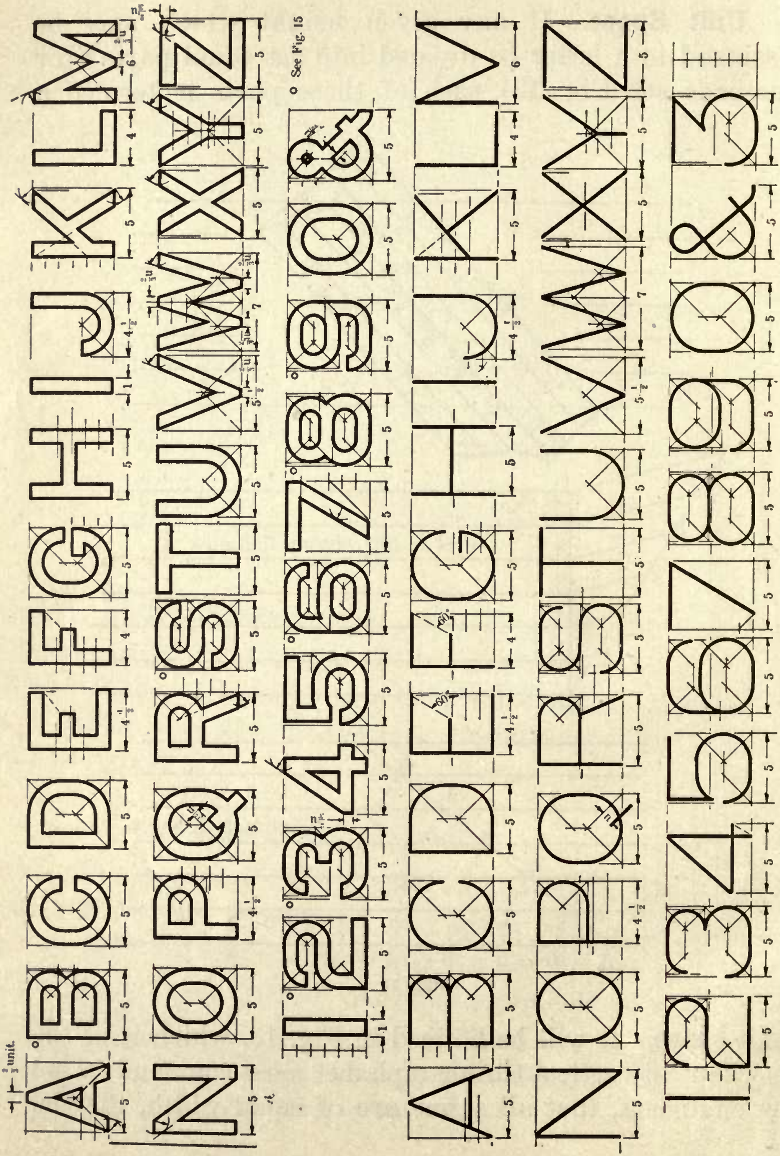


Fig. 13

one unit. Either an **extended** or **compressed** style of letter may be obtained by arbitrarily increasing or decreasing the unit.

CONSTRUCTION OF LETTERS

(7) In constructing a word or series of words, the rectangles which will enclose the individual letters can be laid out most rapidly by the method shown in Fig. 14. The vertical distance at the left extremity of the line is

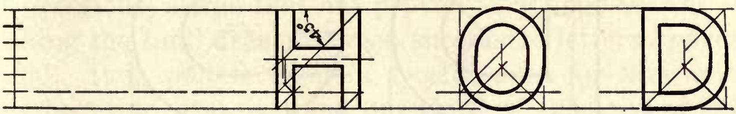
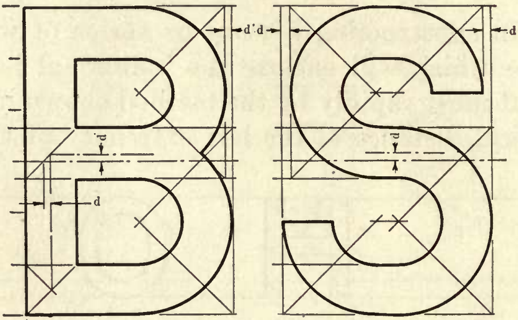


Fig. 14

first divided into six units. Any desired number of units, e. g., 5 for the letter **H**, may then be carried any distance to the right, by means of the T-square, to the left side of the **H** rectangle, and then by means of the 45° triangle to the upper guide line, thereby obtaining the location of the right side of the rectangle. The unit width of letter stems and other necessary construction may also be secured thru the proper use of the 45° triangle as shown in Fig. 14.

For letters involving arcs of circles, after the enclosing rectangles have been drawn, the centers may easily be located as shown in Fig. 14 and as indicated for other similar letters in the Gothic alphabet, Fig. 13.

In the construction of the letters **B**, **E**, **F**, **H**, **R**, and **S**, it should be noted that the intermediate horizontal stroke is slightly above the center; for **A**, **G**, and **P** it is below. The letters **B, E, R, S, X,** and **Z,** and the numerals **2, 3, 5, 6, 8,** and **9,** Fig. 15, will have a more pleasing appearance if the width of the top section is less than that of the bottom.



The distance d may vary from 1/6 to 1/4

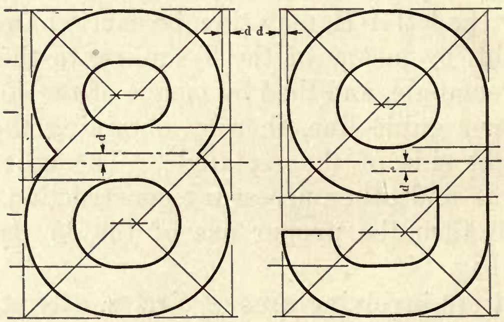


Fig. 15

SPACING

(8) Having learned the correct shapes of the individual letters, it becomes necessary to direct particular attention to their combination into words and sentences

in headings, signatures, titles, name plates, etc. While it may be aptly said that beautifully formed letters can result only by a process of designing each stroke as it is executed, this is more especially true of the completed title page or other group of letters, taken as a whole, where as much judgment is employed in the determination of the areas to be left white as those to be made black.

Methods of Areas. As a help in securing good spacing by eye alone, a rule that has proven very good is that of making the total areas between successive letters *appear* equal. It is well to adopt a specific area for this unit. The best unit area is about **one-third** of the *area* of the letter **M**; this is equivalent to a *linear* spacing of 2 units.

KEY TO TABLE, FIG. 16.

To obtain the space, in *units,* to be allowed between any letter, e. g., A, and any letter of the alphabet which may follow it in a word, it is seen in the table, Fig. 16, that between A and BDEF, etc., one unit space should be left and between A and CGO, etc., one half unit. In every case the spacing given is that to be allowed between the letter given in the first column and any letter of the alphabet which may follow it in a word.

	2	1¾	1½	1¼	1	¾	½	¼	0	Neg.
A					BDEFHI KLMNPR	U	CGOQSZ	AX	JTW	VY
B			BDEFHI KLMNPR	CGOQSU	Z	X	AJTWY	V		
C			BDEFHI KLMNPR	CGOQSU	Z	X	AJTWY	V		
D			BDEFHI KLMNPR	CGOQSU	Z	X	AJTWY	V		
E				BDEFHI KLMNPR	CGOQSU	Z	X	AJTWY	V	
F						BDEFHI KLMNPR	U	CGOQST VWXYZ		AJ
G			BDEFHI KLMNPR	CGOQSU	Z	X	AJTWY	V		
H	BDEFHI KLMNPR	U	CGOQSZ	X	AJTWY	V				
I	BDEFHI KLMNPR	U	CGOQSZ	X	AJTWY	V				
J		BDEFHI KLMNPR	U	CGOQSZ	X	AJTWY	V			
K				BDEFHI KLMNPR	U	CGOQSZ	X	AJTWY	V	
L						BDEFHI KLMNPR	U	ACGOQS XZ	J	TVWY
M	BDEFHI KLMNPR	U	CGOQSZ	X	AJTWY	V				
N	BDEFHI KLMNPR	U	CGOQSZ	X	AJTWY	V				
O			BDEFHI KLMNPR	CGOQSU	Z	X	AJTWY	V		
P					BDEFHI KLMNPR	U	CGOQSZ	TVWXY	AJ	
Q			BDEFHI KLMNPR	CGOQSU	Z	X	AJTWY	V		
R			BDEFHI KLMNPR	CGOQSU	Z	X	AJTWY	V		
S			BDEFHI KLMNPR	CGOQSU	Z	X	AJTWY	V		
T					BDEFHI KLMNPR	U	CGOQSZ	TVWXY	A	J
U		BDEFHI KLMNPR	U	CGOQSZ	X	AJTWY	V			
V						BDEFHI KLMNPR	U	CGOQST VWXYZ		AJ
W					BDEFHI KLMNPR	U	CGOQSZ	TVWXY	A	J
X				BDEFHI KLMNPR	U	CGOQSZ	X	AJTVW Y		
Y					BDEFHI KLMNPR	U	CGOQSZ	TVWXY		AJ
Z			BDEFHI KLMNPR	U	CGOQSZ	X	ATVWY	J		

Fig. 16

Special Cases. The method of areas just suggested can be easily applied in spacing the complete rectangular letters, H, M, etc.; and after some practice will not be found difficult for the curved letters. There are, however, letters which require attention in almost every

Fig. 17

arrangement in which they occur. In Fig. 17 is shown a word involving **A, F, L, T, and Y,** all of which, together with **J, P, and V,** are difficult to combine with other letters and maintain good spacing because they differ so greatly in width at the top and bottom. When **L** comes before **A** it is wise to decrease its width one-quarter unit. So, also, when **T** follows **F, P, T, V, W,** or **Y,** its width should be reduced one-quarter unit. **A** after **F** and before or after **T, V, W,** or **Y,** should be set much closer than when used with other letters, in some cases the spacing being even negative, i. e., the **F** overlapping the **A,** Fig. 17. Other changes will suggest themselves.

Crowding Letters. One of the common errors made by beginners is that of crowding the straight stroke

Fig. 18

letters too close together and separating the oval letters too far; this always results in making the inking look heavier in some places than in others, Fig. 18.

Spacing of Compressed and Extended Letters. In the latter part of Art. 3 it was shown that wide variation in the resulting appearance of an alphabet may be secured by modifying the proportions of the oval element. It should be kept in mind, when performing an exercise in any altered style, that good appearance, i. e., uniformity of shapes, equality of spacing, smoothness of effect, can be produced in only one way: All letters and spaces must be reduced or enlarged in the same proportion. That is, if the letters are decreased one-third their normal widths then the values given in Fig. 16 must be decreased one-third also, in order to give the proper spacing to be used. Thus, suppose the word shown in Fig. 19 (a), if constructed of normal letters, is found to be either too long or too short for the space available for it. In (b) and (c) of this figure are shown the same word constructed

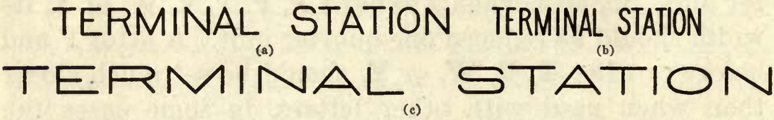


Fig. 19

in compressed and extended styles respectively. In each form, however, it will be seen that the distance between straight stroke letters, as that between M and I, conforms to that prescribed in Art. 8; that is, it is one-third the width of the letter M. The *values* given in the *table*, Fig. 16, may be used *directly* by simply taking as the *unit* for *spacing* **one-sixth** the **width** of the **M** in the particular style used. The stems of compressed and extended letters have the same width as the stems of normal letters, i. e., one-sixth of the height. The method here outlined is applicable to both vertical and slant styles.

Mechanical Spacing. In the table, Fig. 16, is given in terms of a sub-division of the standard unit space, the spacing that is approximately correct, according to good design, for any combination of letters. If this table be given some careful study in connection with the principle explained in the paragraph, "Method of Areas," it will be possible after some little practice to design rapidly without constant reference to the table for the correct spacing.

NAME PLATES

(9) **Definition.** A *name plate* is a small metal plate fastened to a machine or structure and should contain the following information: *Name* of the *machine* (unless it is so common as to be perfectly familiar to everyone), *name* of the *manufacturing company,* and *address* or *location* of the *company's works* or *factories.*

DRAWING TITLES

(10) **Definition.** A *working drawing title* is a condensed statement of the following information: *Name* of the *piece* of *machinery* drawn, *name* and *address* of the *manufacturing company, initials* of the *draftsman, checker,* and *tracer, scale, drawing number,* and other necessary *filing data.*

GENERAL ORDER OF WORK IN CONSTRUCTION OF WORKING DRAWING TITLE

(11) **Given data.** In making up a *working drawing title* the draftsman ordinarily has given him a certain amount of data as follows: "Details *of* Horizontal Milling Machine, *manufactured by the* Landis Tool Company, Waynesboro, Penna.; drawn by (R. C. S.), checked by (————), traced by (————), scale ½″=1″, *draw-*

ing finished April 2nd, 1915." The above material, condensed, must be placed within a given title space, perhaps 3"x5".

Elimination of unnecessary material and arrangement into groups. In order that the given material may be placed within the given title space, every unnecessary word must be eliminated. Running thru the given data it is seen that the words italicized can be omitted without the least danger of misunderstanding the remainder. With these words omitted the remaining data seems to group itself naturally as follows:

(1st prom.) **Horizontal Milling Machine.**

Details

(2nd prom.) **Landis Tool Co.**

(3rd prom.) **Waynesboro, Pa.**

Drawn by (——), Checked by (——), Traced by (——),
(4th prom.) **Date (——), Scale (——).**

Order of prominence. In a *drawing title* as well as in a *name plate,* certain groups of words are more important than others. In the *drawing title* the *name* of the *piece of machinery* is, of course, given most prominence; while, in the case of the *name plate* the *name* of the *manufacturing company* should be given *first* prominence. In the *drawing title* the *name* of the *manufacturing company* will be given *second* prominence, *address* of the company *third,* and the remaining information, being about equally important, should be given *least* prominence and arranged as desired. The word "**Detail**" or "**Assembly**", which may be either included or omitted as desired, will not figure in the order of prominence.

Methods of securing prominence. In both advertising and drafting there are in use two methods for securing prominence of any one group of words over another. The one most generally used is **variation in height** of the letters of the various groups, to correspond in general to the order of prominence established; if this is not possible thru lack of space, a **distorted** letter, either of odd construction or of the *compressed* or *expanded* style, may be used. One may then depend on the odd appearance of the letters to give to that group of words the desired prominence. In the case of *drawing titles* and *name plates* the first method, i.e., *variation in height* of letters is preferable.

Margins and margin lines. Before sketching in the guide lines for the various groups of words, *margin spaces* should be determined and *light margin lines* ruled in Fig. 20. In doing this certain rules of design must be adhered to; the upper and lower margins may be of any desired width; however, for best appearance they must be *equal*. The right and left margins, tho not necessarily equal to the upper and lower, must be *equal* to *each other.* In a rectangular space whose *width* is *greater* than the *height,* better effect is obtained if the *right* and *left margins* are made slightly *greater* than the *upper* and *lower;* if the reverse is true of the rectangle then the right and left margins should be less than the upper and lower.

Guide lines. To obtain the guide lines for the various groups of words, produce the lower margin line to the left until it intersects the border of the title space at A, Fig. 20, and from this point draw up and toward the right a line at an angle of about 60 degrees with the horizontal. Selecting any desired distance at the rela-

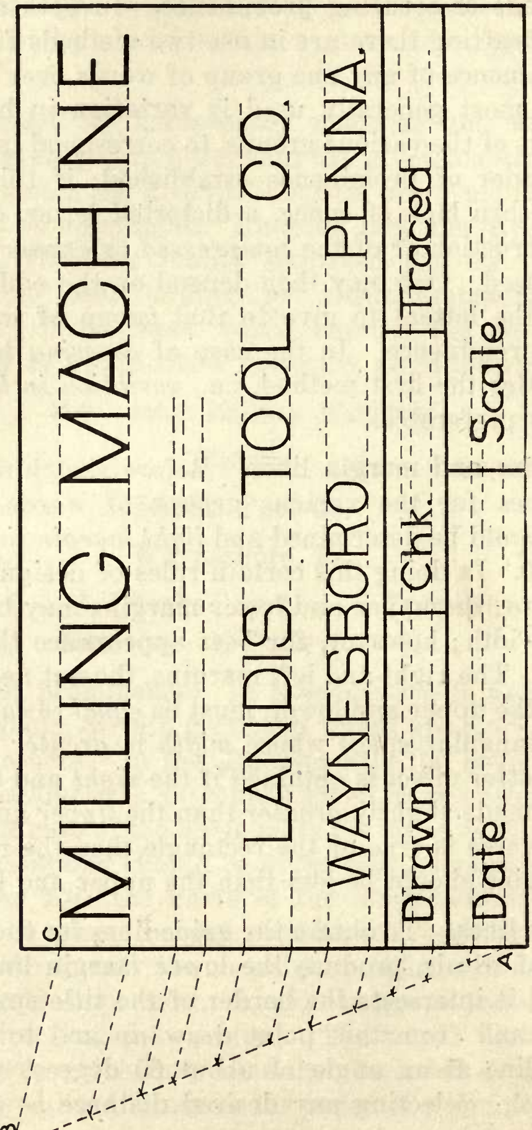

MILLING MACHINE
LANDIS TOOL CO.
WAYNESBORO PENNA.
Drawn
Chk.
Traced
Date
Scale
A
B
C

Fig. 20

tive height of the letters of the lower group, lay off this distance from A along the 60 degree line; then a relative distance for the space between this line and the line next above; next a relative space for the letters of the next group and so on until all of the groups have been accounted for along the 60 degree line. From the last point, B, draw a line, B C, as shown in figure and from the various points along the line A B draw lines parallel to B C until they intersect the border line, A C; the required guide lines will then be found the same relative distances apart as the points plotted on the line A B.

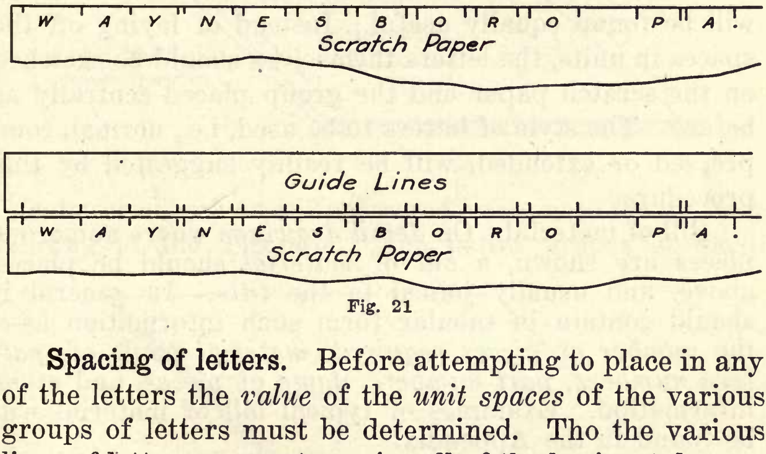


Fig. 21

Spacing of letters. Before attempting to place in any of the letters the *value* of the *unit spaces* of the various groups of letters must be determined. Tho the various lines of letters may not require all of the horizontal space allotted to them, for best appearance they must be placed centrally; i.e., with equal margins at their right and left. To accomplish this, rule in a vertical center line of the title space and use the following method:

Scratch paper method. Select any point close to the left end of the straight edge of a sheet of scratch paper,

Fig. 21, and from this point step off with the large and small dividers the proper number of unit spaces in succession, for the various letters and spaces between letters, marking with the divider points the location of the *beginning* and *end* of each letter. Placing the scratch paper centrally along the lower guide line of the space into which this group of letters is to go, mark with the needle point the position of the beginning and end of each of the letters. This method has the advantage of centrally placing the entire group and of locating the various letters at the same time.

If the letters are to be free hand the above method will be found equally useful. Instead of laying off the spaces in units, the letters themselves should be sketched on the scratch paper and the group placed centrally as before. The style of letters to be used, i.e., normal, compressed or extended, will be readily suggested by this procedure.

Bill of material. On *detail drawings* where numerous pieces are shown, a *bill* of *material* should be placed above, and usually joined to the *title*. In general it should contain in tabular form such information as—the *number* of *pieces required, material* made of, *pattern numbers, part numbers, name* of *pieces,* and other information. Examples of typical bill of material will be found in the Appendix.

GUMMED LETTERS

(12) For those who have an appreciable amount of work on titles, signs, etc., the gummed letters sold by the Ticket and Tablet Company, of Chicago, and which are shown in their exact sizes and styles in the appendix, will be found a great convenience. The many uses which such letters serve need not be enumerated. They are made in red, white, and black.

CHAPTER 2

USE OF INSTRUMENTS

DRAWING-BOARD

(13) **Construction.** Drawing-boards are made of either poplar or white pine, the right and left edges, Fig. 1, being reinforced by cleats of some harder wood. These

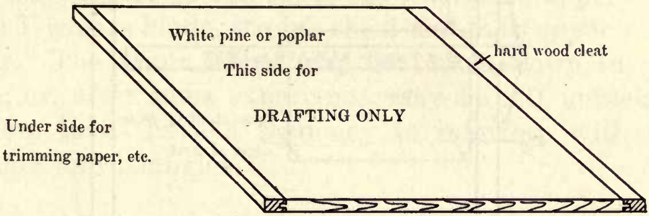


Fig. 1

cleats serve both as stiffeners and as runners for the easy sliding of the T-square. The better grades of small

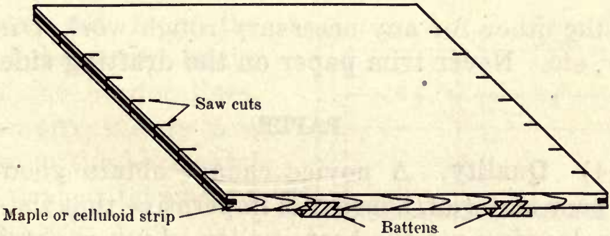


Fig. 2

boards are reinforced on the back by two *battens,* Fig. 2, and ordinarily, have inserted in their right and left edges a wearing strip of either hard maple or celluloid, instead of the cleats of Fig. 1. It will be noticed in Fig. 2 that the right and left edges of the second class of board are broken at intervals by saw cuts which prevent the inserted strip of hard wood from expanding and splitting the wood.

Use. The two sides of the type of board shown in Fig. 1 have very definite uses if the board is to be kept in shape for good drafting. The one side for *drafting*

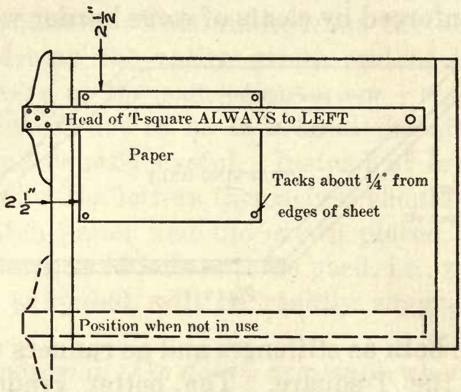


Fig. 3

only, the other for any necessary rough work, *trimming paper*, etc. **Never trim paper on the drafting side.**

PAPER

(14) **Quality.** A novice cannot obtain good work from poor material, hence it is imperative that the beginner in drawing use the best quality of paper obtainable. A heavy, hard surface paper of the quality of Keuffel & Esser's **Normal**, or E. Dietzgen's **Napoleon** is recommended.

Position of paper on board. In tacking the paper to the board, Fig. 3, keep the sheet well toward the *top* and to the *left;* about two and one-half inches from the upper and left edges. This should be done in order that the draftsman may work to advantage on the bottom of the sheet, and that it may not be necessary to work to any great extent on the end of the T-square blade, which cannot be prevented from springing slightly.

Tacking sheet. Place *upper left* corner of sheet in approximately correct position and tack to the board, Fig. 3, placing tacks close to the corners of the paper. Then after lining up the upper edge with the upper edge of the T-square blade, stretch sheet and tack *upper right* corner. The lower edges may be tacked down in any order; or, after some experience, may be left untacked, as these tacks have a tendency to interfere with the T-square and triangles.

BORDER LINES

(15) The *border lines* as well as all other construction work done by the draftsman should be placed in by measurements from *center lines* and **not** from the *edges* of the *sheet.* In the case of the border lines, the measurements are made from the horizontal and vertical center lines of the sheet, Fig. 4.

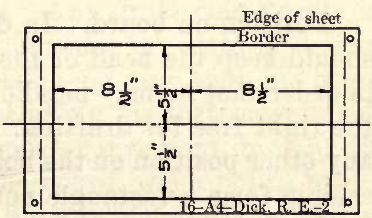


Fig. 4

T-SQUARE

(16) **Construction.** Both the **blade** and the **head** of the T-square, Fig. 5, are of hard wood, hence the glue

cannot cement them very tightly together; neither do the short screws hold very firmly; a fall, even to the floor, may break the joint and damage the T-square. Keep the T-square out of danger of any such fall.

In case the joint breaks, take out screws, rough both head and blade with coarse sandpaper, coat well with Dennison's glue, place blade at 90° with head with triangle, tighten screws and let stand a day. Then take out screws and put in round-headed wood screws long enough to run through and project an eighth of an inch or more. File off screws carefully. Be sure screws are tight. It may be advisable to bore small holes entirely through head and blade for these large screws, to prevent splitting of the wood.

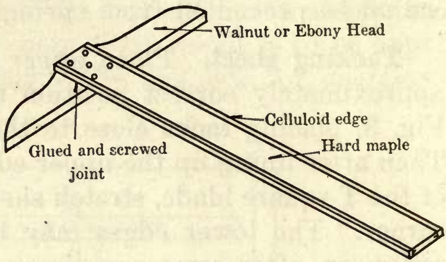


Fig. 5

Position on board. In drafting, a right-handed man should keep the head of the T-square to the *left,* Fig. 6, in order that he may handle it with his left hand, leaving the right free for drafting. **Never place the T-square in any other position on the board,** as the edges of the board seldom form a rectangle nor is the head of the T-square likely to make exactly 90 degrees with the blade.

Use of blade. The *upper edge* of the blade should be used for *drafting* only; and the draftsman will do well to take excellent care of this edge, for once nicked or dented the instrument is practically ruined for good work. The *lower edge* may be used as a *cutting ruler* but **never** for *drafting.*

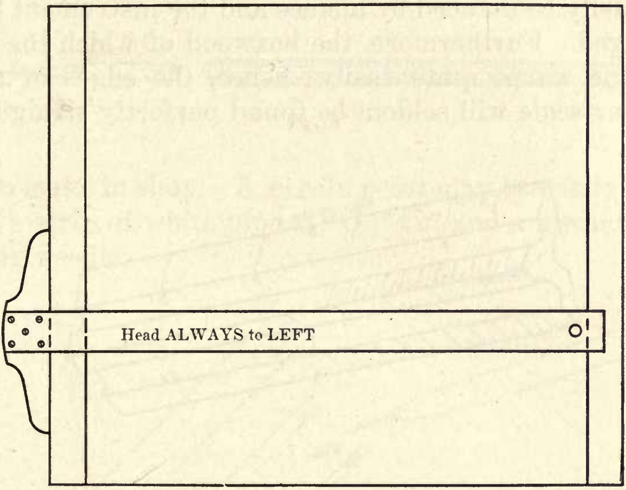


Fig. 6

Position when not in use. Any draftsman profits by keeping his drawing instruments in certain definite places, so that as far as possible he may keep his attention entirely on his work, handling his instruments subconsciously. It is found most convenient to slip the T-square to the bottom of the board, when not in use; it is here out of danger, out of the way, yet easily accessible.

To keep clean. A drawing may easily be smudged by a dirty T-square, so it will be well to give the blade a thoro cleaning with a damp cloth or piece of art gum at frequent intervals.

SCALE

(17) **Care.** The scale should **never** be used as a *ruler* because, as a drafting instrument its efficiency depends upon the condition of its edges, and these edges can easily be defaced by misuse and the instrument badly damaged. Furthermore, the boxwood of which the scale is made warps quite easily; hence, the edges of a triangular scale will seldom be found perfectly straight.

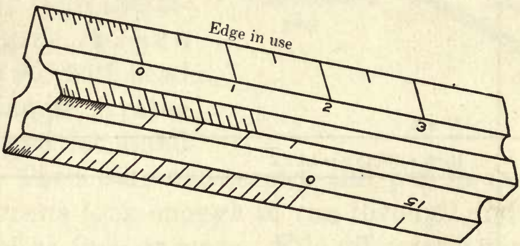


Fig. 7

Use. On inspection, Fig. 7, it is seen that the numerals are all placed on the scale so as to appear upright only when one works *over the top* of the scale or on the edge *away* from the draftsman and *not toward* him. All dimensions should be taken directly from the scale as it lies on the drawing and **not** by means of the dividers. The *needle point* is the best aid in obtaining dimensions with perfect accuracy. The pencil point is a poor substitute for the needle point.

NEEDLE POINT

(18) **From Richter type of instruments.** An excellent *needle point* for obtaining dimensions may be made

up by inserting into the long *knurled barrel* furnished with every set of Richter type of instruments, the *small point* which is provided for converting the large compass into a set of dividers, Fig. 8.

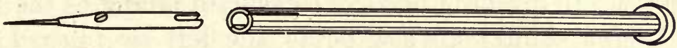


Fig. 8

To make in shop. A *needle point* may be easily made from a strip of white pine ¼″x¼″x2″ and a medium size sewing needle.

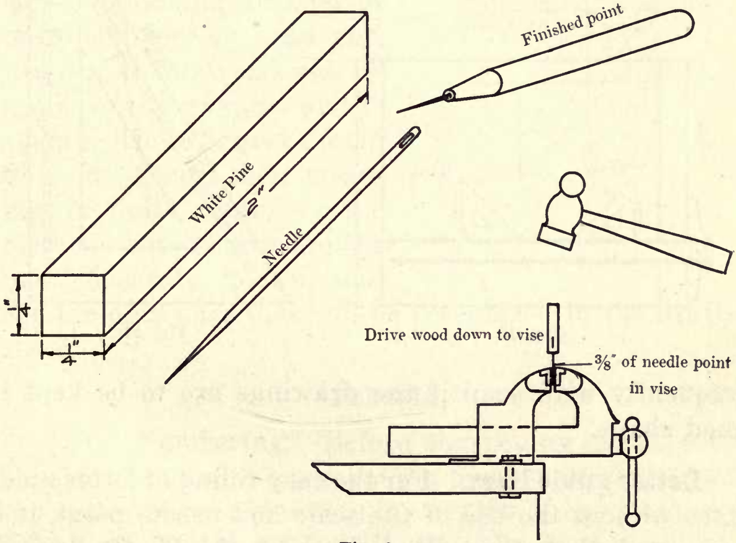


Fig. 9

Construction: Fig. 9. Insert the needle in a vise, point *down,* with about ⅜″ of the point in the vise, and carefully drive the strip of pine over the exposed part of the needle; the wood may then be shaved round and pointed slightly at the needle end.

TRIANGLES

(19) In drawing *vertical lines* with triangles the *vertical edge* should always be to the **left** or *toward* the *head* of the T-square, Fig. 10.

To clean. The surface of the celluloid triangles quickly becomes smudged from erasings and pencil dirt that may be on the drawing; hence, they must be cleaned

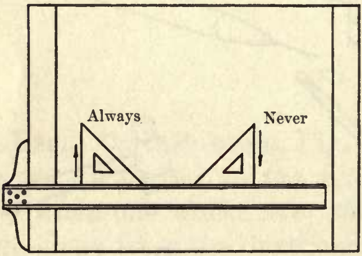


Fig. 10

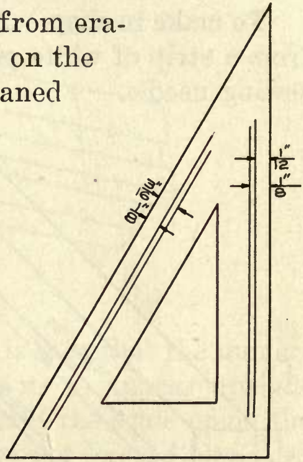


Fig. 11

frequently with soap if the drawings are to be kept in good shape.

Letter guide lines. For the easy ruling of letter guide lines without the use of the scale and needle point, it is suggested that along the edges of the 30x60 *triangle* light lines be scratched with the needle point as follows: Along the *hypothenuse* and 1/8″ from the edge scratch carefully a fine line; also a second line 3/16″ from the edge; along the long leg scratch two lines 1/8″ and 1/12″, respectively, from the edge, Fig. 11. After the lines have been scratched they should be smeared over with India ink, rubbing the ink into the scratches with the fingers. After the ink has dried for a few minutes the surplus may be rubbed off with a cloth. Turning the triangles over with the scratched lines against the paper, it is seen that they now stand out very sharply, and may be used in ruling guide lines for any necessary lettering.

Parallel and perpendicular lines. In Figs. 12 and 13 are shown a number of methods of obtaining a series of parallel lines, or lines perpendicular to given lines, by means of the *triangles* and *T-square.* These figures should be studied until their meaning is quite clear, as the methods here shown are the most accurate known, and are the only ones that will be recognized in the drafting room.

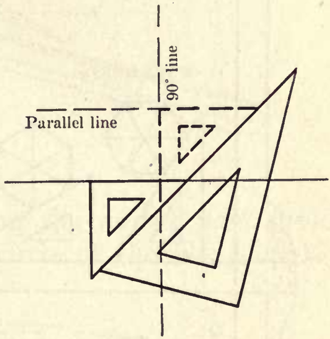


Fig. 12

PENCILS

(20) **Numbering.** Before sharpening either end of the pencil, cut with a pen knife a number of nicks toward the center to correspond to the degree of hardness; e. g., four nicks for 4H, six for 6H, etc., Fig. 14.

Sharpening wood. In sharpening, trim the wood carefully on both ends of the pencil, back a distance of about one inch from the ends, leaving about ¼″ of the lead exposed, Fig. 15. One end is to be sharpened to a *round point,* the other to a *wedge.* In shaping up both of these points, use the pencil point file provided in the kit.

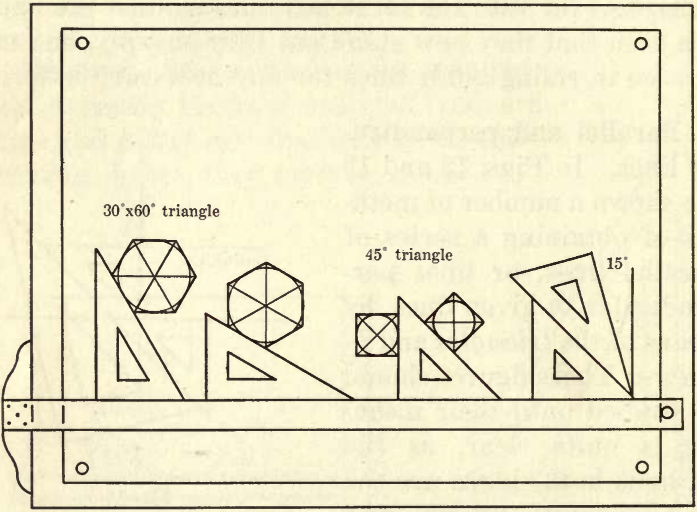


Fig. 13

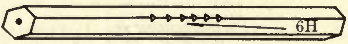


Fig. 14

Round point. In shaping up the round point, hold the pencil at an angle of about 45 degrees with the axis of the file. As the lead travels over the file, Fig. 16, revolve the pencil slowly between the thumb and fingers, attempting to give it a complete revolution with each stroke. The lead may thus be easily sharpened to a perfect cone. In this sharpening be careful that the point extends the *full length* of the lead exposed.

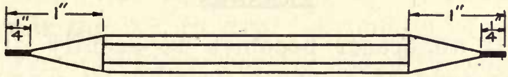


Fig. 15

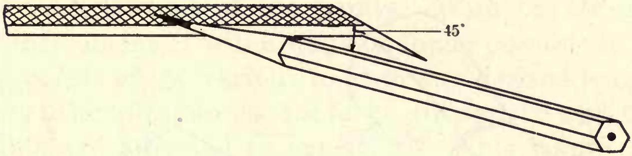


Fig. 16

Wedge point. In sharpening the *wedge point* hold the pencil perpendicular to the axis of the file, Fig. 17,

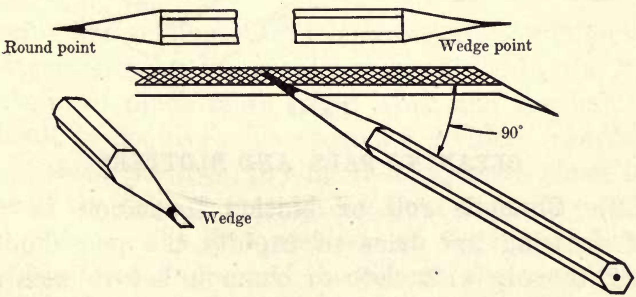


Fig. 17

and so inclined to the plane of the file that the lead may be sharpened the full quarter inch exposed.

Use of points. The *round point* should be used for drawing *short lines* and *lettering,* the *wedge point* for *long lines;* the round point dulls rapidly in drawing a long line and will make a line of varying weight.

ERASERS

(21) If an eraser becomes apparently *greasy* and smudges instead of cleans a drawing, it may easily be cleaned by rubbing it with another eraser or by rubbing it on the rough surface of the drawing-board itself.

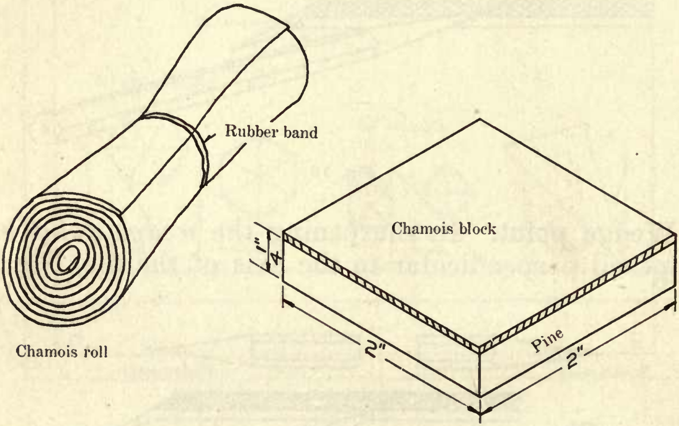


Fig. 18

CLEANING PADS AND BLOTTERS

(22) **Chamois roll or block.** Inasmuch as water proof drawing ink dries so rapidly the pen should be cleaned thoroly with cloth or chamois before each refilling. In addition to this cleaning it will be found possible to obtain more clear cut work if after each three or four lines the point of the pen is scraped over a piece of chamois. A convenient cleaner may be made by roll-

ing up a 2″x 4″ piece of chamois and binding it with a rubber band, Fig. 18, or by pasting a 2″x 2″ piece on a small block of wood.

Blotters. Never attempt to blot drawing ink. The ink is too heavy to be absorbed by blotting paper. Always permit the ink to dry. A puddle of ink may, however, be removed by the careful use of the corner of a blotter.

LARGE DIVIDERS

(23) **Adjustment of the points.** With the *Richter* type of instrument, it will always be found possible to adjust the points of the various tools to any desired length; so, before attempting to use the *large dividers* be sure that the points are adjusted to exactly the same length and that they are in perfect shape. In case the points of the *Gem Union* instruments are not of the same length, it will be necessary to grind the long point down on a small **carborundum** stone. Keep points always in perfect shape for good work.

Opening and setting. It is desirable always to handle each instrument with the *right hand* unaided by the *left;* this permits of much more rapid work and the habit is not difficult to acquire. To *open* the divider, *insert* the *thumb between* the *legs,* prying them apart a short distance until the fingers may be inserted and the *one leg* grasped *between* the *first* and *second fingers,* the *other between* the *third finger* and the *thumb;* the head of the instrument should rest against the knuckle of the first finger. Holding the instrument in this position it is found easily possible to adjust the points to any desired distance.

To place point. *To place* the one *point* of the divider at any *point* on the sheet, rest the *wrist* at a convenient distance from the point; it will then be found easily possible to place the *point* of the *leg between* the *third finger* and the *thumb* in any desired position. Raising the wrist and keeping the little finger on the paper, the other leg can now be adjusted for any desired distance. It is perhaps as good practice and may be found easier for some to steady the hand thruout the operation by merely resting the little finger on the paper, instead of the wrist.

Stepping off distances. After the points have been placed as desired, to *step off* a certain distance a number of times, raise the first finger to the top of the head, then, releasing the other leg, *grasp* the *head between* the *first finger* and the *thumb* and step off the distance by swinging the dividers alternately *over* and *under*. Handling the instrument in this way it will not be necessary to take a new grip on the head thruout the operation.

LARGE COMPASS

(24) **Adjustment.** To adjust the *needle point* of a *compass* to both the *pencil* and *pen, remove* the *pencil point* and *insert pen;* after *adjusting* the *needle point* so that its *shoulder,* **not the point,** *is flush* with the *end* of the *pen, remove pen* and inserting *pencil,* adjust *lead* until it is *even* with the *shoulder* of the *needle point.*

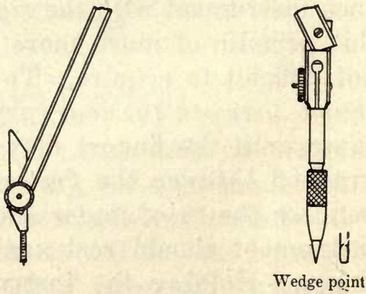


Fig. 19

Use. For *adjustment* of *leads* to any desired *radius*, and placing *needle point* at any *desired center*, see **Large Dividers**, Art. 23. For describing arcs with the large compass the legs should be adjusted as shown in Fig. 19.

IRREGULAR CURVE

(25) The irregular curves are those which cannot be drawn readily and accurately with the compass. The general directions of the different portions of such curves are first determined roughly by a number of plotted points at as small intervals as possible (the positions of these points are obtained either by mathematical coordinates or mechanically from other projections or views of the same curve). Before drawing the curve mechanically it is best to draw lightly a freehand curve thru the plotted points, then carefully piece by piece the mechanical curve may be drawn. In drawing the mechanical curve two things must be kept in mind; first, that the final curve must coincide as absolutely as possible with the freehand curve; second, that the curve must be "smooth," i. e., it must have no sudden glaring changes of curvature or "humps." The failure of a novice to obtain a good irregular curve is due to perhaps two causes: first, that he starts with the assumption that it is too easy to require any attention, and second, that he is too easily satisfied with a very indifferent job. Curves having curious "humps" may be termed freaks and are seldom, if ever, encountered in Mechanics.

It is difficult to recommend any curve or even several curves as being even approximately universal, so no such advice will be attempted. A great number of such curves are listed in all instrument catalogs and special requirements will have to be depended upon in any selection.

However, two curves have found much favor among students and are recommended for general use. One of these has obtained the name of "Banana" curve, Fig. 20, and the other is the G. E. D. Special, Fig. 21.

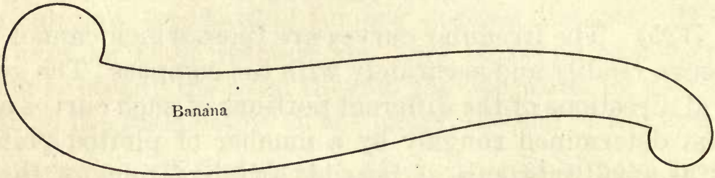


Fig. 20

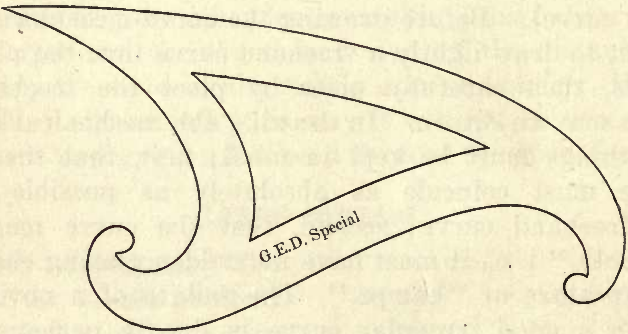


Fig. 21

BOW DIVIDERS

(26) **Adjustment.** (See **Adjustment** for **Large Dividers.**)

Placing at center. (See same for **Large Dividers.**)

Opening and closing points. With the *center adjustment* instrument, which is always preferable to the *side* *adjustment,* after placing the one point at a given point on the sheet, *raise* the *first finger* to the *head* and *turn* the *adjustment screw between* the *second finger* and *thumb* until the points are apart as desired.

Stepping off distances. (See same for **Large Dividers.**)

BOW PENCIL

(27) **Hard lead.** To obtain satisfactory work from the *bow pencil* the lead should be extremely hard, at least 6H. Ordinarily, the lead supplied with instruments is not more than 2H or 3H, and wears down too rapidly. Try the lead before using it on a drawing, and if found soft, substitute for it a piece of lead from a 6H pencil.

Sharpening lead. Since the bow pencil is, like the bow dividers, an instrument of precision, for small arcs the round point will be found more convenient than the wedge. Inasmuch as the total amount of use is small compared with that of the large compasses, the need of a wedge point to diminish the number of times required to shape it up, is not great enough to overbalance the inaccuracy and awkwardness of the latter in drafting. It is well to shape the point as long as the construction of the instrument and the strength of the lead will permit. Fig. 22.

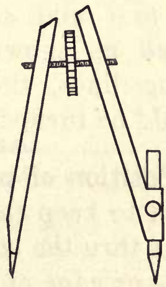


Fig. 22

Adjustment to any radius. In *adjusting* the *points* to any *desired radius,* instead of obtaining the dimension *directly* from the *scale,* it will be better to *transfer* this *radius* to the *paper* by means of the *scale* and *needle point,* and set the bow pencil from this as explained under **Large Dividers.**

Describing arcs. In *describing* an *arc* with either the compass, bow pencil or pen, the direction of motion of the lead should be *clockwise* and thru the total length of the desired arc before taking the point from the paper, Fig. 23.

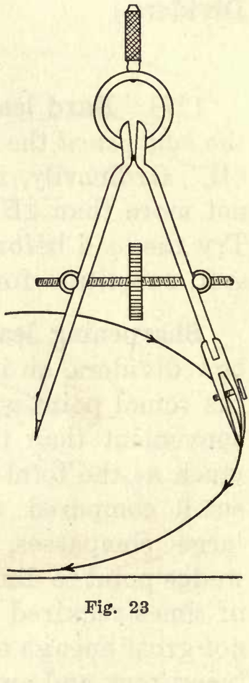


Fig. 23

RULING PEN

(28) **Manner of holding.** The *ruling pen* should be held *between* the *first* and *second fingers* and *thumb* as shown in Fig. 24. In ruling lines, the *adjusting screw* should be turned *from* the user.

Position of pen. Unless care is taken to keep the pen in a *vertical plane* thru the *edge* of the *T-square blade* or *edge* of the *triangle,* Fig. 25, trouble may be experienced in the ink running under the T-square blade, Fig. 26, or in a badly broken line, Fig. 27.

Tilted in the direction of motion. For best results the pen should be *tilted* slightly in the *direction* of the motion, Fig. 24; this permits one to inspect the work of the pen as it travels. A greater angle than 10 or 15 degrees may however permit the ink to run down and cause a blot.

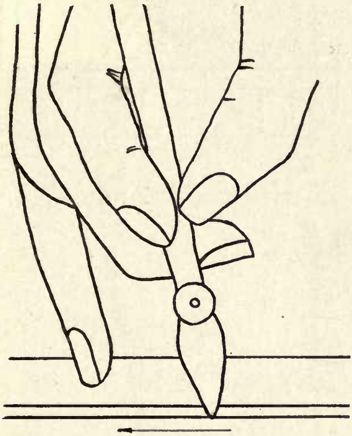


Fig. 24

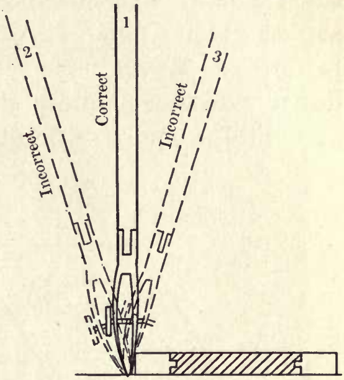


Fig. 25

Effect of Position 2

Ink ran under T square

Fig. 26

Effect of Position 3

Pen riding on one nib

Fig. 27

To fill pen. To *fill* the pen, always use the *quill* supplied on the stopper of the ink bottle. **Never dip the pen into the ink.** If by chance any ink has gotten on the outside of the pen, wipe it off carefully before using; it may save a serious blot.

Direction of motion in ruling lines. In *ruling lines,* either with the *pen* or *pencil,* the direction of motion should be *from left* to *right* or from *bottom* to *top* of the sheet, Fig. 28. Ruling lines thus, it is always possible to see what the pen or pencil is doing. **Never** rule lines **down** the sheet unless they are oblique and are being put in with the triangle.

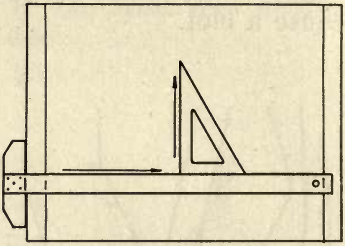


Fig. 28

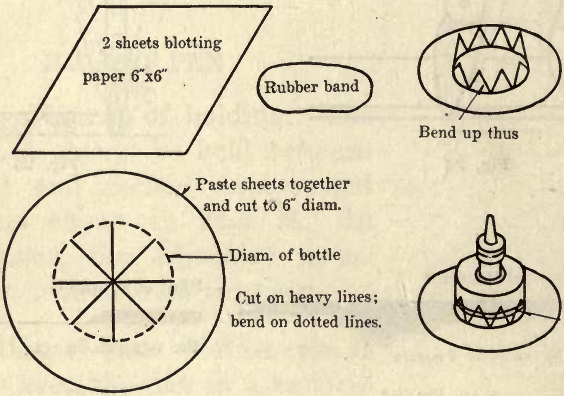
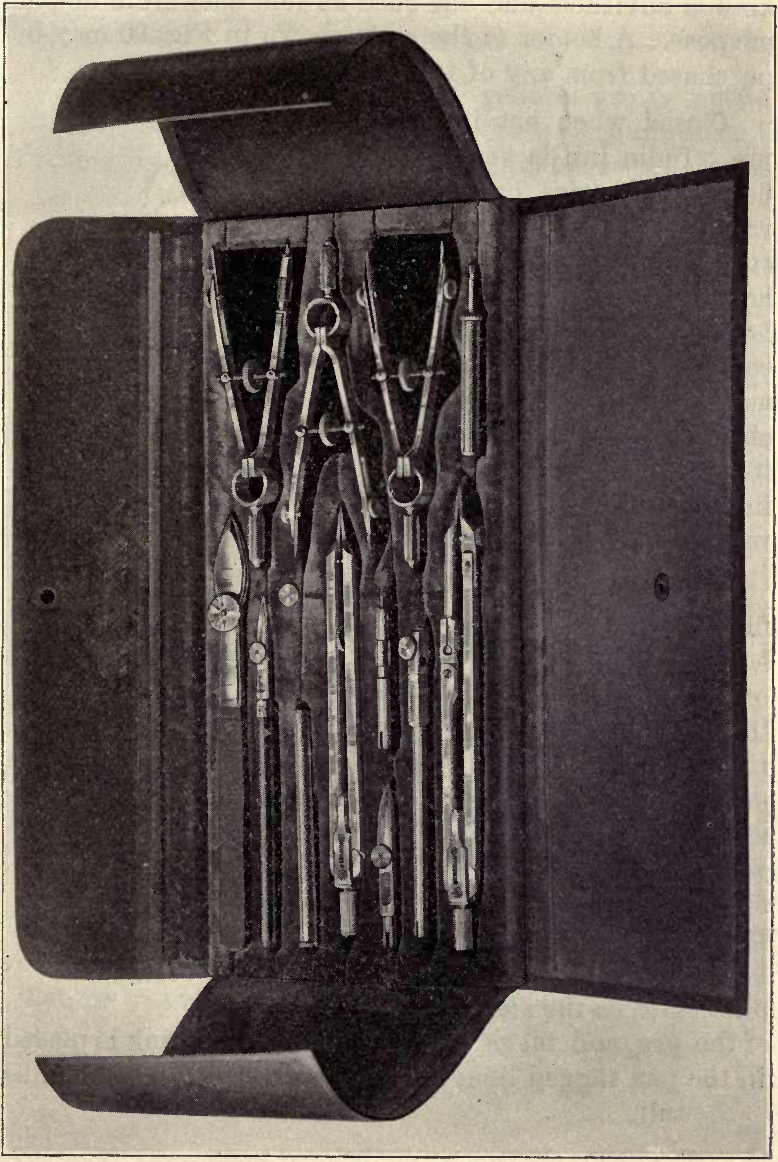


Fig. 29

INK BOTTLES

(29) **Holder.** A convenient holder for the ink bottle may be made from two sheets of blotting paper and a rubber band as shown in Fig. 29. A holder of some



kind is advisable and one such as this answers a double purpose. A holder of the style shown in Fig. 30 may be purchased from any of the instrument companies.

Closed when not in use. India ink is very heavy and dries quite rapidly; hence, if the stopper is left out of the bottle even for several hours the ink may become so heavy as to make it impossible to obtain good work from it. Be sure to **close** the bottle carefully after each refilling of the pen. With proper treatment the ink will remain in good condition for several years.

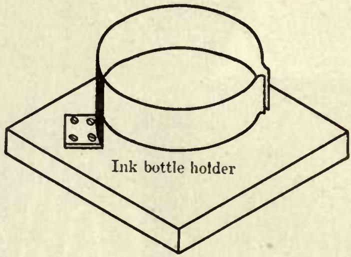


Fig. 30

To open bottle and fill pen. To open the bottle without danger of upsetting, *grasp* the *neck between the third* and *little fingers,* Fig. 31, and the *stopper between* the *first finger* and *thumb* of the **same hand**; after removing the stopper, *place* the *quill between* the *nibs* of the *pen,* and fill as desired. If too much ink is placed in the pen ragged lines and perhaps serious blots will be sult.

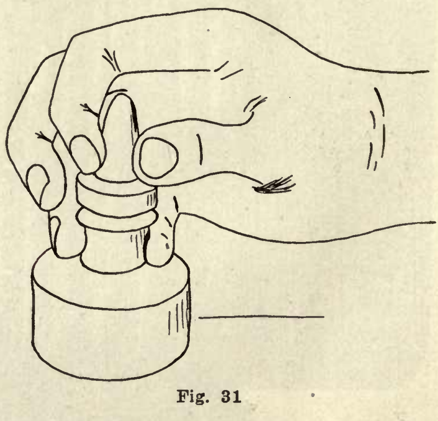


Fig. 31

PROTRACTOR

(30) The protractor in most general use is a semicircle of celluloid, horn or metal whose circumference is divided into degrees and perhaps half degrees. On the

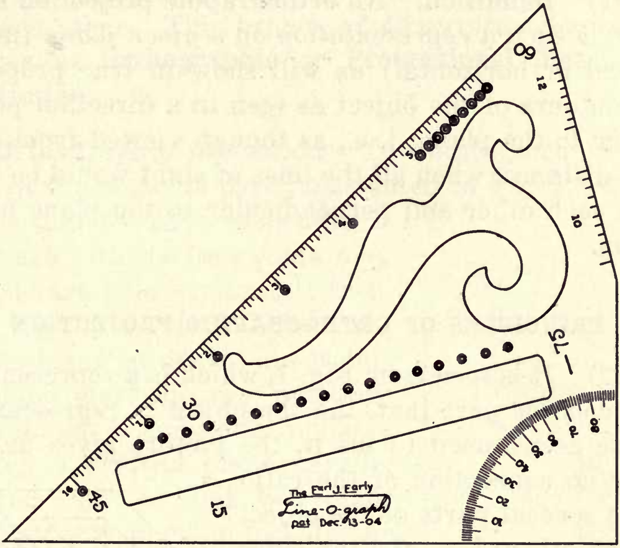


Fig. 32

Line-O-Graph, Fig. 32, is shown a 90° protractor which without any handicap can be substituted for the usual 180° instrument. To measure any desired angle, the center of the circle is placed at the vertex, and 0° on one side of the given angle. The value of the angle may then be read directly from the quadrant.

CHAPTER 3

ORTHOGRAPHIC PROJECTION

(31) **Definition.** An orthographic projection of any object is such a *representation* on a *given plane* (usually vertical or horizontal) as will show in true proportion the contours of the object as seen in a direction perpendicular to the plane; i. e., as though viewed from an infinite distance, when all the lines of sight would be parallel to each other and perpendicular to the plane of projection.

PRINCIPLES OF ORTHOGRAPHIC PROJECTION

(32) It is seen from Fig. 1, which is a representation of a machine part that, tho the object is represented as we are accustomed to see it, the picture gives us absolutely no conception of the ratio of the several parts of the object to each other; i. e., tho the sides of the square hole in the top may appear to be equal to the thickness of the object, one has no means of knowing exactly what

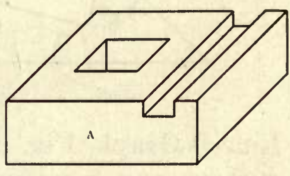


Fig. 1

the relation is; hence, unless actual dimensions were given for every detail of such a drawing, and these dimensions could be depended upon to be absolutely accurate, one would have no means of making, except approximately, the object which the drawing represents. Hence, it will be appreciated that in making drawings for the use of workmen in shops, such an application of *Descriptive Geometry* should be employed as will represent each line of the object at least once, in its *true mathematical ratio* to other lines; i.e., such a representation, that if no dimensions were given, one could compare lines by means of a scale or dividers and be certain of their exact ratio to each other. This branch of *Descriptive Geometry* is known as **Orthographic** or **Proportional Measurement Projection.**

Orthographic projection. To obtain such a projection of the machine part represented in Fig. 1, let us imagine that we have suspended it in space with the face containing the square hole horizontal; then, see Fig. 2, let us imagine that four *planes* be drawn about this machine part in the positions shown, one, a *horizontal* plane, a second a *vertical* plane parallel to the face A, and two other planes perpendicular to both the *vertical* and *horizontal* planes just drawn.

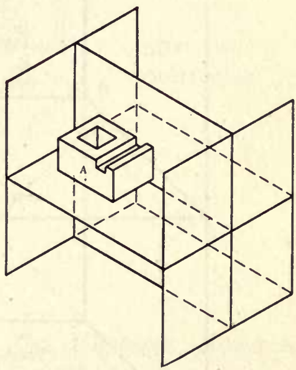


Fig. 2

Coordinate planes and coordinate angles. The *three planes* just constructed about the machine part in Fig. 2 are known in orthographic projection as **coordinate planes** and are named individually, the **Horizontal** or **H plane, Vertical** or **V plane, Profile** or **End plane**; see Fig. 3. The *four* dihedral *angles* formed by the H and V planes are known as **1st, 2nd, 3rd,** and **4th** and are numbered in the order shown.

Projections or orthographic representations. In explaining the method used in obtaining the *orthographic representations* of the machine part, the corner A, Fig. 4, will be taken as typical of all significant points of

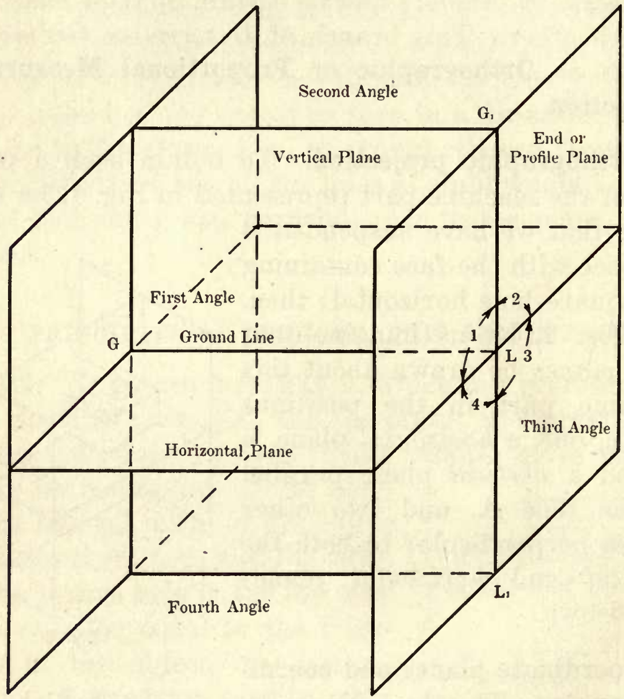
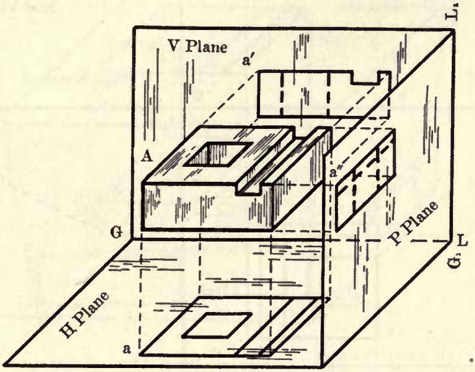


Fig. 3

the object. It is desired to represent this point on each of the three coordinate planes, the second End plane being for the time eliminated. From point A are dropped three perpendiculars, one to each of the coordinate planes; the points in which these perpendiculars pierce these coordinate planes are known as the **projections** of point A, and are called, **V** or **Vertical projection** or **Front View** (*always lettered a′* if lettered at all), **H** or **Horizontal projection** or **Top View** (*always lettered a* if lettered at all), and **Profile, End Projection, End** or **Side View** (*always lettered a″* if lettered at all); if then from all of the *points* of the object *perpendiculars* were dropped to the *Vertical plane* and *lines* drawn connecting the *piercing points* of these *perpendiculars* in regular



FIRST ANGLE PROJECTION

Fig. 4

order, Fig. 4, we would have on the *Vertical plane* a *drawing* or *projection* representing perfectly the *appearance* of the *front* of the machine part; a similar process would give us on the *Horizontal plane* a correct representation of the *top* of the object and on the *End plane* a representation of the *side* of the object.

1st and 3rd angle projections. If the object be placed in the *1st angle,* as in Fig. 4, the projections referred to above are known as **first angle projections.** If the object is placed in the *3rd angle*, as in Fig. 6, the projections are known as **third angle projections**; i. e., the projections of an object are known as *First* or *Third Angle projections* according to the *angle* in which the *object* is *placed*. It should be noted that Figs. 4 and 6 show only those

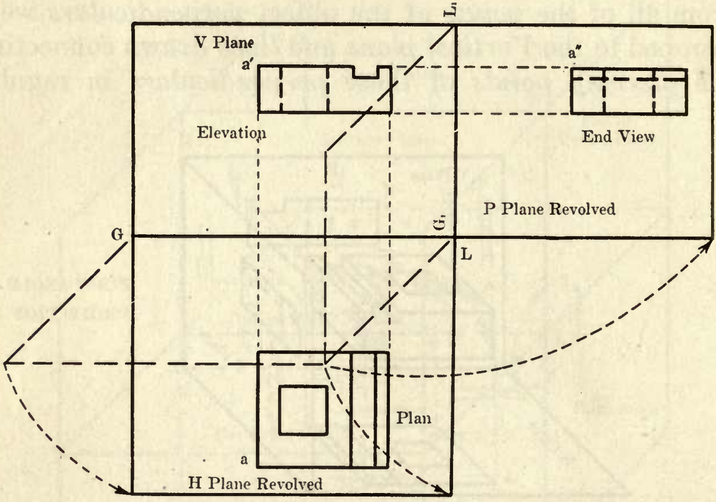
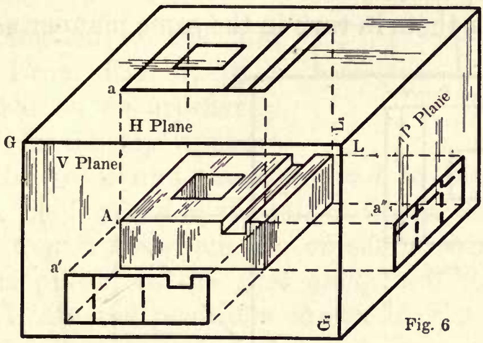


Fig. 5

parts of the coordinate planes that enclose the angle of projection under consideration. No mention is made of the Second or Fourth Angle projections because it would be impracticable to use either as working drawings.

Revolution of coordinate planes. Already an apparent difficulty has arisen in the question of how to represent all of these projections, e.g., of point A, Fig. 4, on a single sheet of paper when in fact the three projections, *a, a′* and *a″*, are found on three planes at right angles to each other. The line of intersection of the *Horizontal* and *Vertical planes* is known as the **Ground Line** or **G L**; the intersection of the *Vertical* and *End planes* is $\mathbf{G_1\ L_1}$. This difficulty can now be solved as follows: Using G L as an axis, Fig. 5, let us imagine that the portion of the *H plane* in *front* of *V* is *revolved down* until it *coincides* with the V *plane*. It should be remembered that the portion of the H plane behind (not shown in the Fig.) re-



THIRD ANGLE PROJECTION

Fig. 6

volves up till it coincides with the V plane above G. L. In this revolution, *a* revolves into the new position, *a,* on the continuation of the perpendicular dropped, from *a′* to G L; for, if thru the two lines *Aa* and *Aa′*, Fig. 4, a plane be passed, it will cut from the V plane a line thru *a′* perpendicular to G L; as *a* revolves about G L down, it revolves in the plane *a′* A*a,* and when it reaches the V plane, must lie on the perpendicular to G L thru *a′*, the line cut from the V plane by the plane *a′* A*a.* Since *a* is before G L the distance A*a′*, *a* will be found below G L the same distance; *a′* is above G L the distance A *a;* hence, the distance from G L to the points *a* and *a′* represents the exact distances which the *point,* of which these are the *projections,* is from the V and H planes. If then, G_1 L_1 be used as an axis and the portion of the *Profile plane* in *front* of V be revolved to the **right,** *a''* comes into the new position *a''*, a distance to the right of G_1 L_1 equal to A*a'* and a distance above G L equal to A*a,* or on the horizontal line thru *a'*.

Projections of objects. Advancing from the point A just discussed, to all other elemental points of the object and projecting them in turn in the same manner as was A,

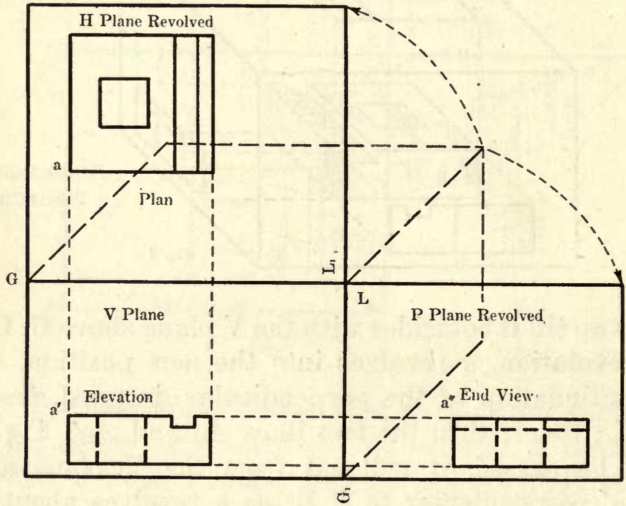


Fig. 7

we find the representation of the machine part in the first angle, when the several points are properly joined by lines, to be as shown in Fig. 5. Proceeding in the same manner with the object in the third angle we obtain the views as shown in Figs. 6 and 7. It should be noted that the views are identical in character but appear in different positions in respect to each other. In practice it is the universal custom to omit both ground lines together with the boundary lines of the three planes. The resulting projections of the object appear as in Fig. 8.

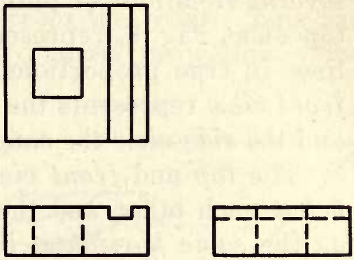


Fig. 8

Elimination of the first angle. From Fig. 1, it is noted that as we ordinarily see objects the *top* appears *above* the *front* and the *right end* to the *right* of the *front* or the *left end* to the *left* of the *front,* according to the position from which the object is seen. When the object is placed in the *first angle* and the projections revolved into the positions shown in Fig. 5, it is seen that the *left end projection* comes in a position to the *right* of the *front* and that the *top* is *under* the *front,* an arrangement by no means natural. While, when the object is placed in the *third angle,* Fig. 6, and projections revolved as shown in Fig. 7, the views assume a grouping identical with their order on the object itself; i.e., the *right end* to the *right* of the *front,* and the *top above* the *front.* Merely for the sake of this natural arrangement the *third angle* will be selected in preference to the *first* in making *working drawings;* i. e., all working drawings will be **third angle orthographic projections.**

SUMMARY OF PRINCIPLES

(33) It may be well to summarize a number of principles brought out in this discussion, likewise to mention several violations of pure orthographic projection. The *top view,* Fig. 8, represents the exact appearance, with lines in true proportions, of the *top* of the object; the *front view* represents the same of the *front* of the object, and the *side view* the same of the *side* of the object.

The *top* and *front views* **must** be *directly above* and *below* each other and the *front* and *end views* **must** be on the *same horizontal lines* as shown in Fig. 7, if the group is to represent the true orthographic projection of the object; a violation of this renders the whole drawing incorrect.

PERMISSIBLE VIOLATIONS

(34) In Fig. 5, it is shown that the portion of the *End* or *Profile plane* in *front* of V is revolved to the **right;** this of course means that the portion of the *Profile plane behind* V revolves to the **left;** while, in Fig. 7, the portion of the *Profile plane behind* V is represented as being revolved to the **right.** This revolution to the **right** of the portion of the *Profile plane behind* V is *orthographically incorrect;* however, in the case of the *third angle* projections it is tolerated for the natural order of projections which it produces.

PROJECTIONS OF HIDDEN LINES

(35) In Figs. 5 and 7 certain lines of the projections are shown dotted lines. This is the custom always followed for showing hidden or invisible lines. For example in the projection on the V plane, the two dotted

lines show that the hole thru the object is invisible when viewed in a direction perpendicular to the V plane. A simple rule for determining the *visibility* of a line is to always consider the *H projection* a *view* from the *top* and the *V projection* a view from the *front.* This applies equally to first and third angle projection. The

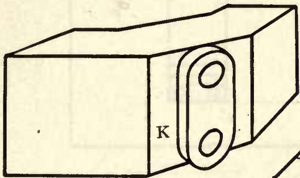


Fig. 9

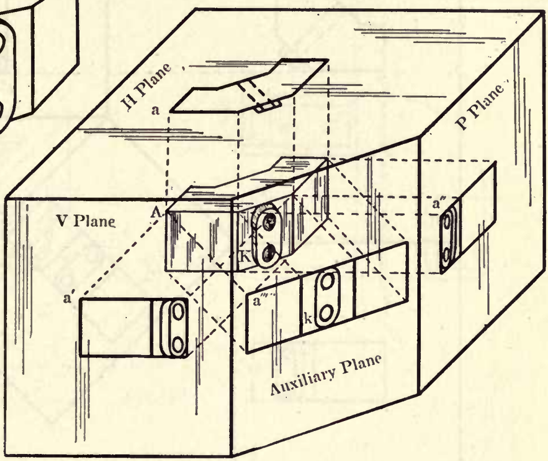


Fig. 10

projection on the P plane is considered a view from the corresponding side of the object, that is, looking perpendicularly thru the P plane at the object.

AUXILIARY PLANES OF PROJECTION

(36) Frequently an object is so shaped that it cannot be placed in an entirely simple position with respect to the planes of projection. The face K on the corner brace shown in Fig. 9 will not be shown in its true size

on either the H, V, or P planes when the object is placed in its simplest position with respect to these planes.

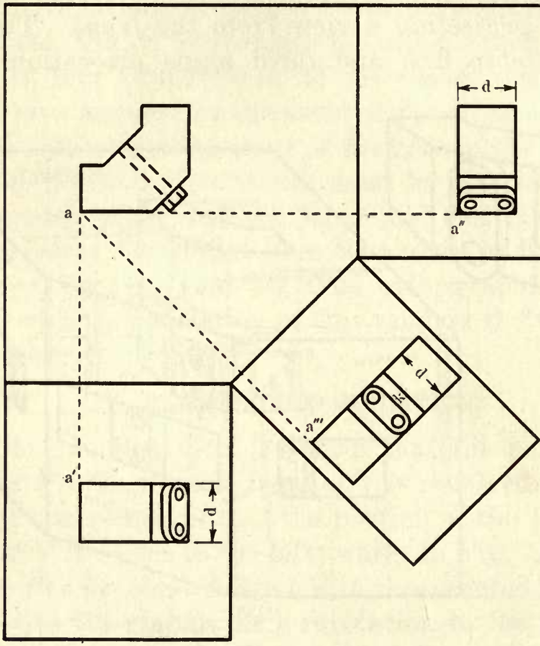


Fig. 11

The use of a fourth plane, which is perpendicular to H but parallel to face K, will give an additional view which will show K in its true size. Fig. 10.

Fig. 11 shows the correct arrangement of the four views of the object after the V, P, and auxiliary planes have been revolved into the H plane.

POSITIONS OF THE THIRD AND FOURTH VIEWS OF AN OBJECT

(37) In Fig. 12 is shown the correct arrangement, orthographically, of the three views of an object-box. However, occasions may arise in which it will be in-

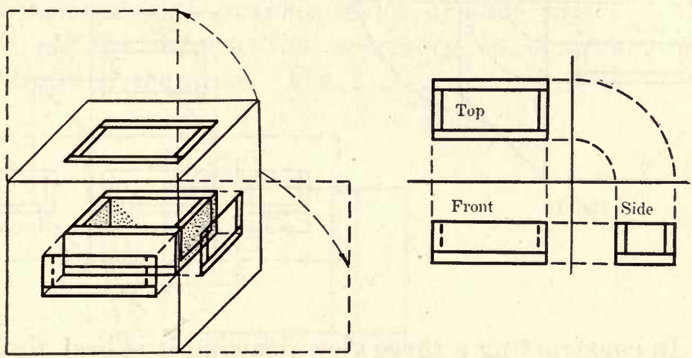


Fig. 12

convenient to place the side view directly *opposite* the *front;* in this case we may imagine that the line of intersection of the end plane and the horizontal plane becomes an axis about which the *end plane* is revolved, Fig. 13, until it coincides with the *horizontal plane.* This entire horizontal plane is then revolved about its line of intersection with V as an axis, until it coincides with V. The side view will now be found *opposite* the *top* instead of the *front.* If two side views are necessary to show the construction they may be placed on *either side* of the *front view,* Fig. 14, or on *either side* of the *top view,* Fig. 15. No other arrangement is permissible.

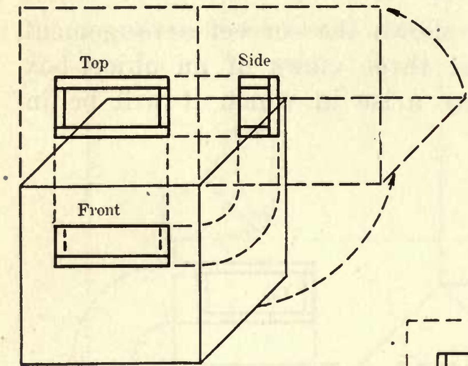


Fig. 13

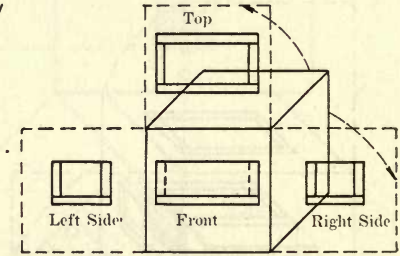


Fig. 14

In constructing a three view drawing it is best always to construct the *top* and *front* views from *dimensions* and by *projection;* then, to obtain the *side* views from these two, entirely by *construction* and **not** by the use of *dimensions.* For the sake of construction the two *ground lines,* Fig. 12, may be drawn in lightly; however, they should be erased when no longer needed.

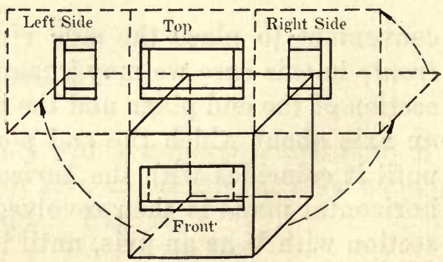


Fig. 15

CHAPTER 4

WORKING DRAWINGS

WORKING DRAWING

(38) **Definition.** A **working drawing** of a piece of machinery is such a *group of correctly and completely dimensioned orthographic views of that object as will give all the information necessary in constructing a duplicate of the same.* Fig. 1.

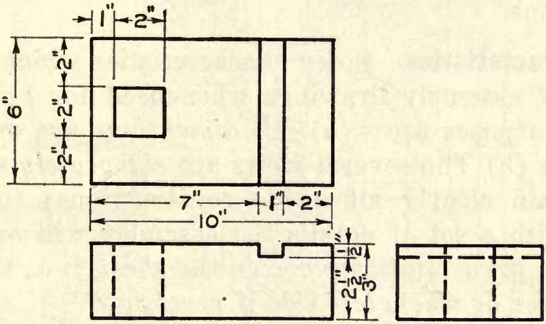


Fig. 1

DETAIL DRAWING

(39) **Definition.** A **detail drawing** is a *working drawing of one piece of any machine.*

A *group* of *detail drawings* of *all* of the *parts* of a machine or any *collection* of *parts* is termed a **set of details.**

ASSEMBLY DRAWING

(40) **Definition.** An **assembly drawing** of a machine is a *one, two or three view orthographic projection of a machine completely assembled;* i. e., all parts in their proper working place. Figs. 2.

Uses. Assembly drawings have three important uses. (1) As an index to a working drawing; i. e., an assembly of a machine is ordinarily given with the set of detail working drawings to explain the use of each of these details in the machine; (2) For purposes of *advertisement* or *magazine illustration;* (3) As a *construction guide* in assembling machines which may be sent out from shops in sections.

Characteristics. Some characteristics which may be noted of assembly drawings when used for any of the above purposes are: (a) All *dimensions* are ordinarily *omitted;* (b) The several views are *elaborately sectioned* to explain clearly all inside constructions; (c) When given with a set of details the assembly will ordinarily *occupy* a *fixed relative place on* the *sheet,* i. e., the *lower left corner* or *whole left side* if necessary.

DETAIL WORKING DRAWINGS

(41) **Arrangement of set of details.** In making a set of details a certain order of arrangement should be followed, both for appearances and ease in reading the drawing. As mentioned under assembly drawings, the assembly should occupy the left portion of the sheet. In general, the arrangement of the details on the sheet should be *such as to suggest their direct relation in the machine itself;* i. e., such an arrangement as is suggested by the relation of these parts in the assembly. It may not always

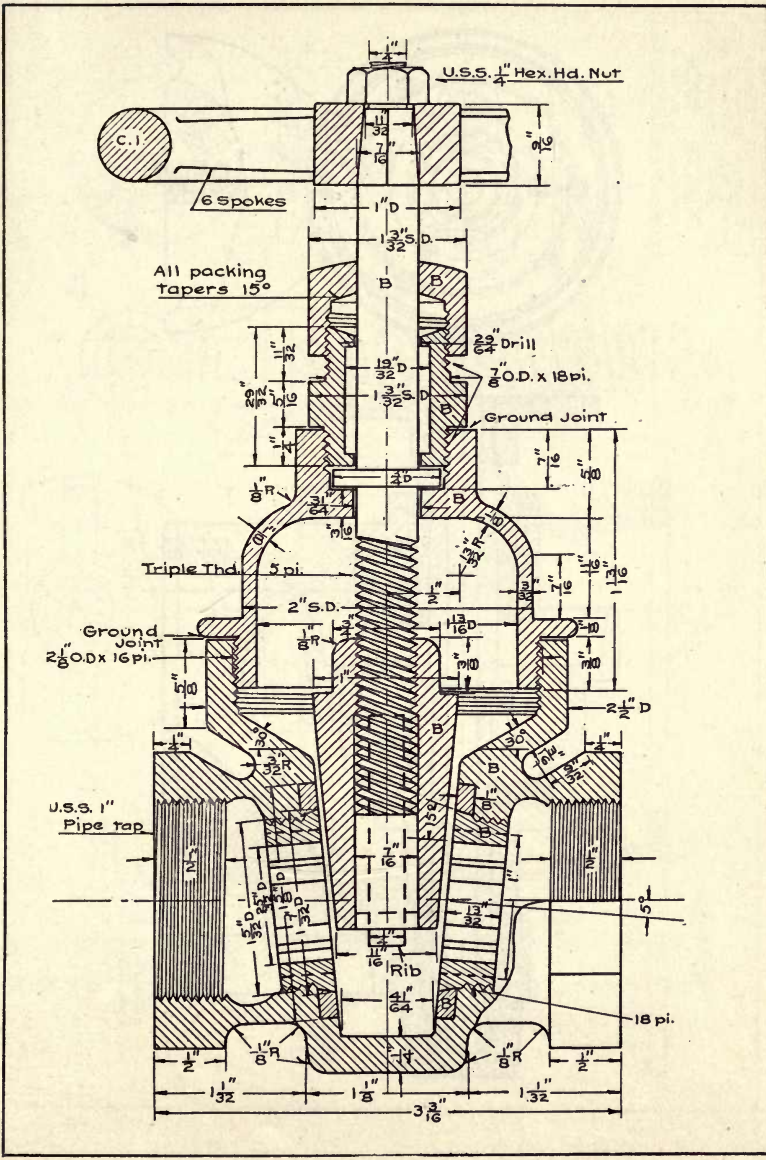

U.S.S. 1/4" Hex. Hd. Nut
C.I.
6 Spokes
1" D
All packing tapers 15°
29/64 Drill
7/8 O.D. x 18 pi.
Ground Joint
Triple Thd. 5 pi.
2" S.D.
Ground Joint
2 1/8 O.D x 16 pi.
2 1/2" D
U.S.S. 1" Pipe tap
Rib
18 pi.
3 3/16"

Fig. 2

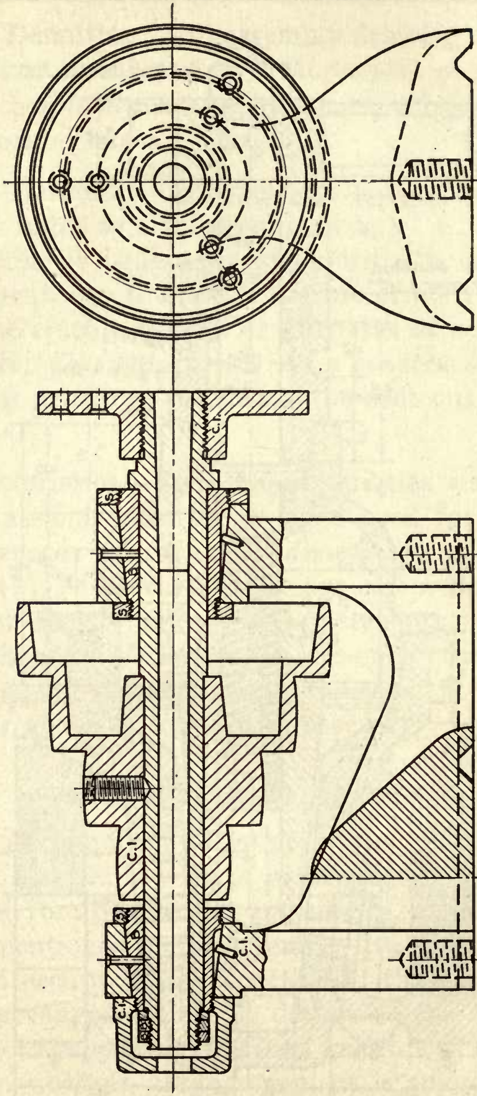


Fig. 2

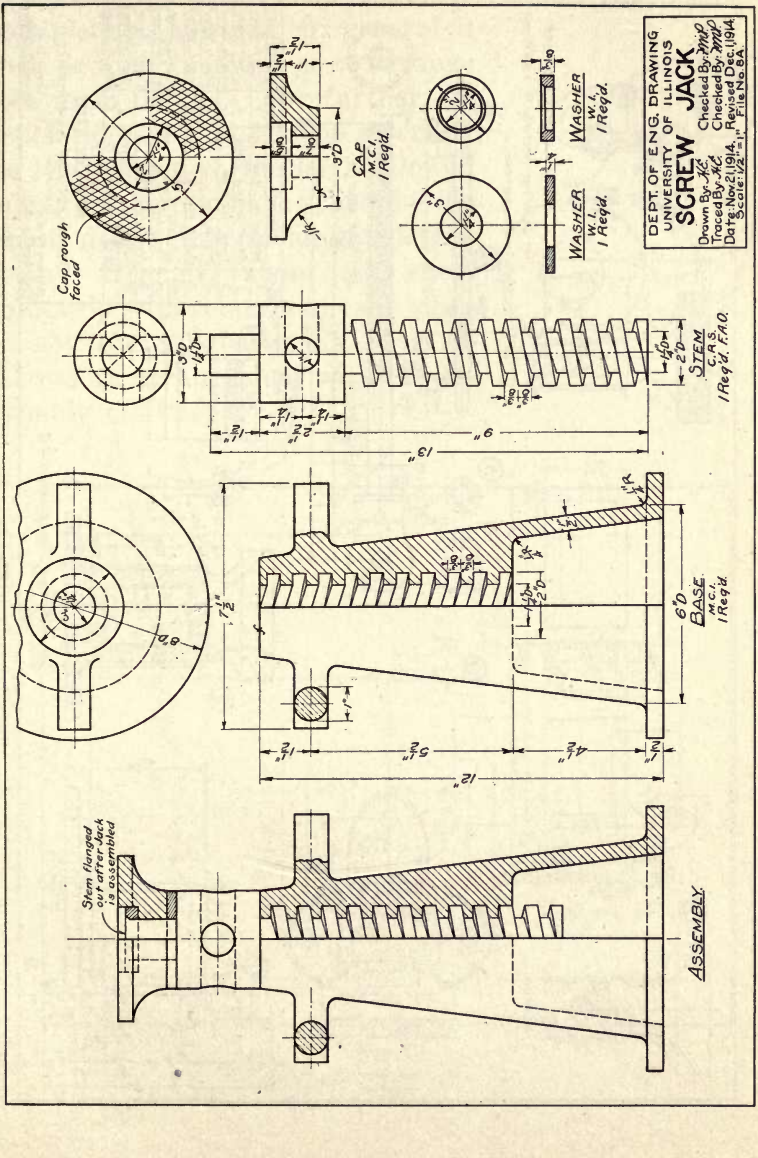

DEPT. OF ENG. DRAWING
UNIVERSITY OF ILLINOIS
SCREW JACK
Date: Nov. 21, 1914.
Revised Dec. 1, 1914.
Scale: 1/2" = 1"
File No. 8A
Cap rough faced
CAP
M.C.I.
1 Req'd.
WASHER
W.I.
1 Req'd.
WASHER
W.I.
1 Req'd.
STEM
C.R.S.
1 Req'd. F.A.O.
BASE
M.C.I.
1 Req'd.
Stem flanged out after Jack is assembled
ASSEMBLY

Fig. 8

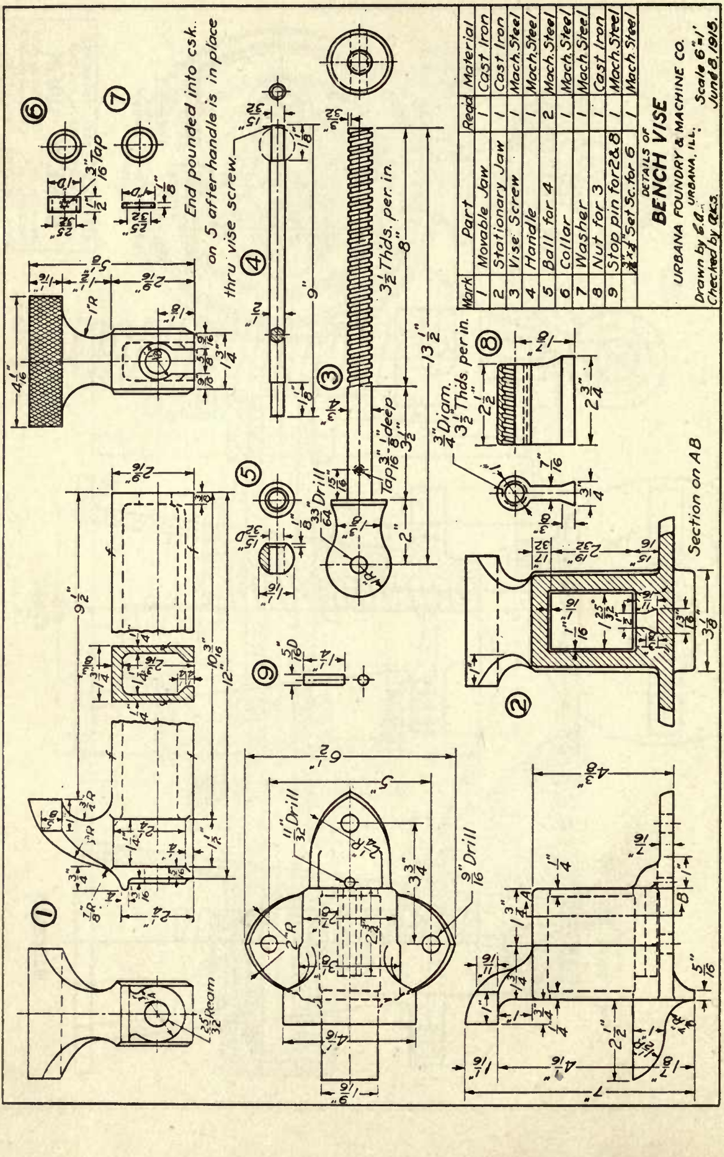

End pounded into csk.
on 5 after handle is in place
thru vise screw.
3 1/2 Thds. per in.
3/4" Diam. 3 1/2 Thds per in.
Section on AB
Mark | Part | Reqd | Material
1 | Movable Jaw | 1 | Cast Iron
2 | Stationary Jaw | 1 | Cast Iron
3 | Vise Screw | 1 | Mach. Steel
4 | Handle | 1 | Mach. Steel
5 | Ball for 4 | 2 | Mach. Steel
6 | Collar | 1 | Mach. Steel
7 | Washer | 1 | Mach. Steel
8 | Nut for 3 | 1 | Cast Iron
9 | Stop pin for 2&8 | 1 | Mach. Steel
 | 3/16"x1/4" Set Sc. for 6 | 1 | Mach. Steel
DETAILS OF
BENCH VISE
URBANA FOUNDRY & MACHINE CO.
URBANA, ILL.
Scale 6"=1'
June 8, 1915.

Fig. 3a

be possible to carry out this scheme completely; however, in general it will be found possible so to arrange the main details. For further explanation see Fig. 3. The assembly is here shown to the left, followed along the bottom of the sheet by the main detail, the remaining details being arranged about the sheet properly with relation to each other if not to the main details. Fig. 3a shows an arrangement with the assembly omitted.

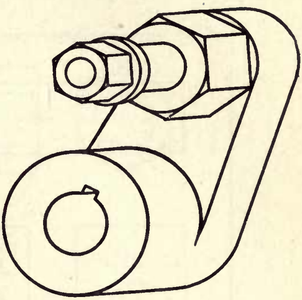


Fig. 4

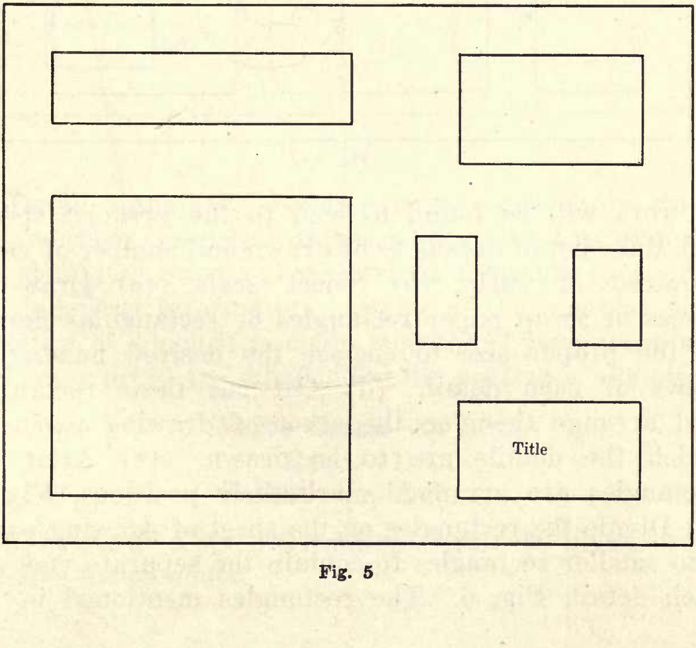


Fig. 5

Order of work in a set of details. In making a set of details, e. g., of the bell crank, Fig. 4, the following order

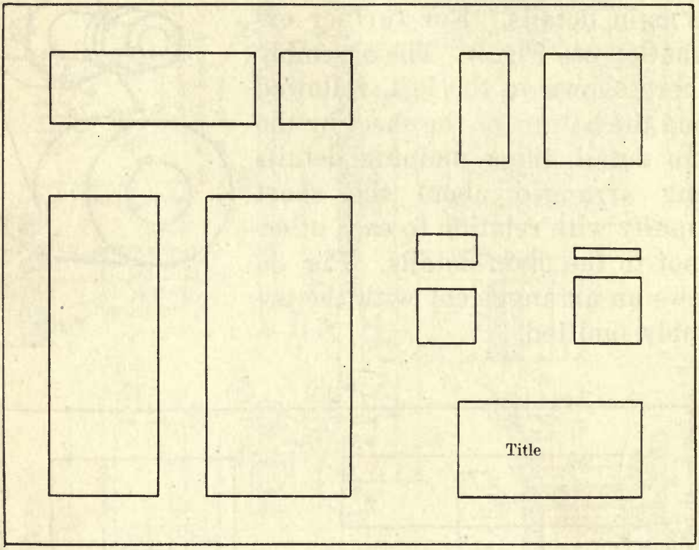


Fig. 6

of work will be found to lend to the greatest speed: (a) Make list of details to be drawn and number of views required of each. (b) Select scale. (c) Draw on pieces of scrap paper rectangles or rectangular figures of the proper size to enclose the desired number of views of each detail. (d) Cut out these rectangles and arrange them on the sheet of drawing paper on which the details are to be drawn. (e) After the rectangles are arranged mark their positions, Fig. 5. (f) Divide the rectangles on the sheet of drawing paper into smaller rectangles to contain the separate views of each detail, Fig. 6. The rectangles mentioned in (e) and (f) should, of course, be put in only lightly and may be erased when no longer needed. Fig. 7.

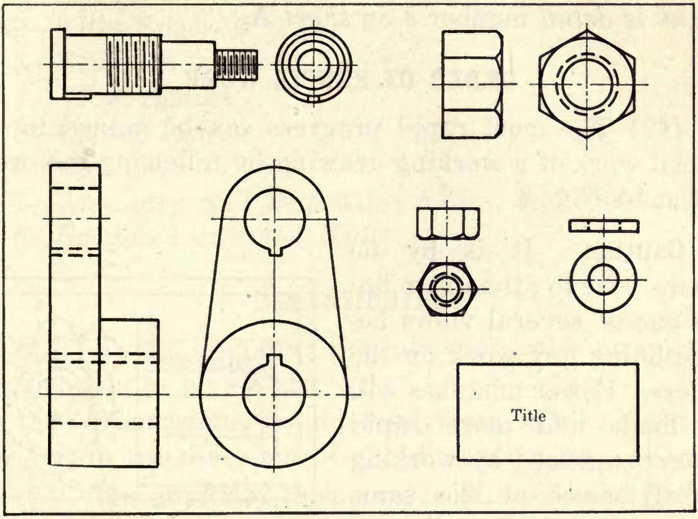


Fig. 7

Detail signature. Accompanying each *detail drawing,* whether the detail drawing be by itself or one of a set, should be given a characteristic **signature** containing the following information: *Name* of the *machine part, material* of which it is made, *number* of *parts required,* and some *arbitrary number* for the *pattern* if the object

Valve Crank—C. I.
Reqd.—1.
Pattern No. A-3.

is to be cast. This information should be given in the manner shown above.

The letter **A** in the *pattern number* refers to the *sheet* **A** of the Details of the Corliss engine of which this *valve crank* is a part; the number **A-3**, indicates that the *valve crank* is *detail* number **3** on *sheet* **A.**

ORDER OF PENCIL WORK

(42) The most rapid progress can be gained in the pencil work of a working drawing by following the order given in Fig. 8.

Caution. It is by no means wise to attempt to finish one of several views before doing any work on the others. Fewer mistakes will be made and more rapid progress gained by working on all views at the same time; i.e., when a line is placed on one view, its projections in the other views should be obtained before proceeding with other lines. All views will thus be finished at practically the same time. When one projection of a line is obtained from a given dimension, the other views of this same line should be obtained by the principle of projection rather than by making use of the scale a second time. This practise, tho it may permit a mistake to remain undetected, has the advantage of producing drawings which are true orthographic projections.

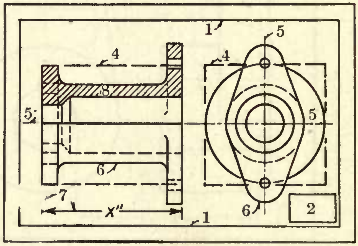


Fig. 8

ORDER OF PENCIL WORK

1—Border Lines
2—Title Space
3—Selection of Scale
4—View Spaces
5—Center Lines
6—Outlines
7—Auxiliary and Dimension Lines, and Dimensions
8—Section Lines and Notes

DIMENSIONING

(43) In *dimensioning* the following rules or suggestions should be observed:

(a) **Dimensions** should read from **left** to **right** or **up,** and in the direction of the dimension line. Fig. 9.

(b) The **auxiliary lines** used in dimensioning should *not quite connect* with the lines from which they lead. Fig. 10.

(c) **Series.** A *series* of dimensions should be given on one *continuous dimension line,* as in Fig. 11, and **not** as in Fig. 12.

(d) An **overall dimension** should **always** accompany a *series,* both as a *check* and for the *convenience* of the workman. Fig. 11.

(e) **Diameters.** *Diameters* should be placed on a *linear diameter* of the circle as in Fig. 13 whenever possible; when necessary to indicate the *diameter* on a *straight line projection* of a circle, the dimension should be accompanied by the letter **D.**

(f) Radii of arcs should be marked R. Fig. 14.

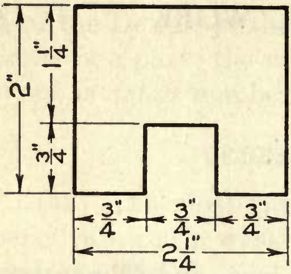


Fig. 9

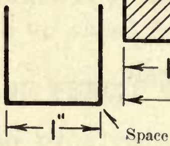


Fig. 10

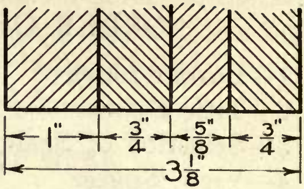


Fig. 11

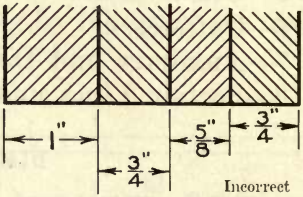


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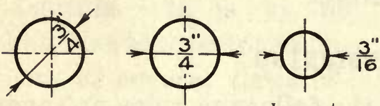
Fig. 12



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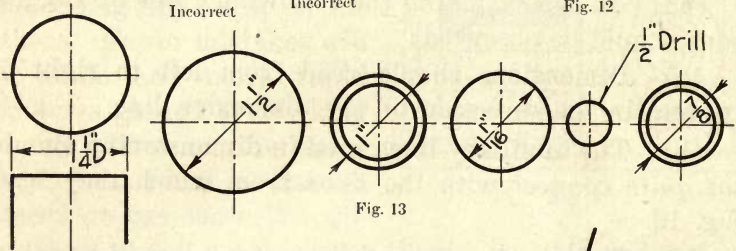

Fig. 13

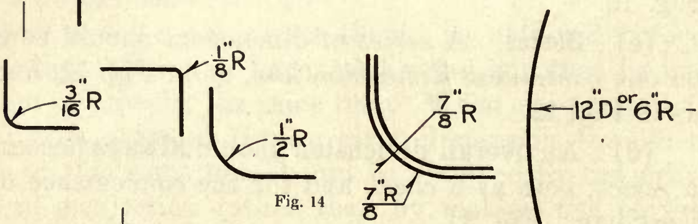

Fig. 14

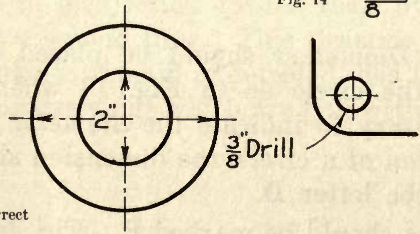

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Fig. 15

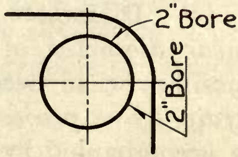


Fig. 16

(g) Inasmuch as the meaning of *hidden lines* is not always clear, it is bad practice to place dimensions on such lines.

(h) Place dimensions between views unless clearness will be gained by placing them otherwise.

(i) Do not repeat dimensions on adjacent views.

(j) Dimensions should not be crowded.

(k) Dimensions always indicate the size of the finished object.

(l) Do not place dimensions *on* or *along Center Lines.* Fig. 15.

(m) In general dimension from the center lines and not from the outlines of the object.

(n) Fractions should be made with a dividing line in the same line with, but not a part of the dimension line. Fig. 11.

(o) The arrows of dimension lines contain two barbs, while those of leaders, Figs. 13 and 16, but one.

(p) Arrows should be so placed that there may be no confusion as to which line they point to.

(q) **Leaders.** All *leaders,* Fig. 16, should be made *mechanically* and **not** *freehand.*

(r) **Notes.** For *explanatory notes* the *leader* should end so that the notes may read either *horizontally* or *vertically* as the *dimensions,* but **not** *diagonally.* Fig. 16.

(s) Dimensions up to two feet should be stated in inches; e. g., 12″, 18″, etc.

Two feet may be written either as 24″ or 2′-0″.

Except for sheet metal, dimensions above two feet should be expressed as follows: 2′-3″, 6′-4″, 7′-0″, etc.

The dimensions for sheet metal should be given in inches and in the order of *thickness, width, length;* e. g., 1/8 x 36 x 120″.

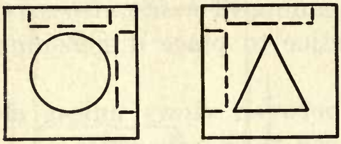


Fig. 17

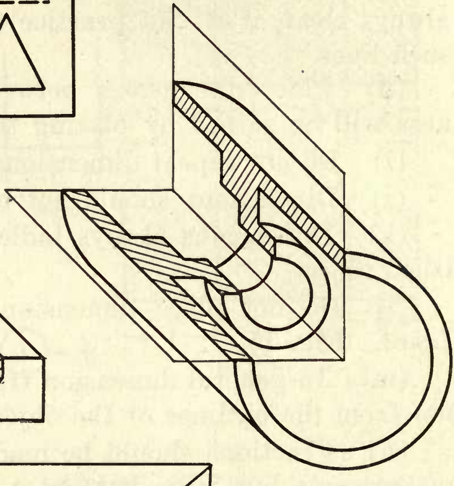


Fig. 18

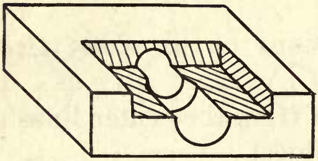


Fig. 19

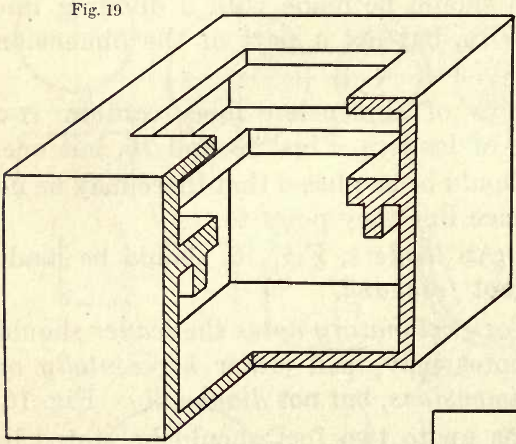
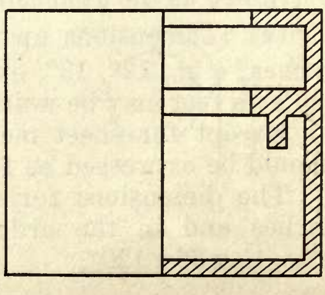


Fig. 20



SECTIONING

(44) The primary function of orthographic projection is, of course, to represent the portions of an object *visible* to the eye. Any constructions *hidden* by the *surfaces in view* may be represented by conventional lines known as **hidden lines**, Fig. 17. The dotted lines in this figure represent the three recesses in the top, front, and side of the cube. It may be satisfactory to represent in this way the interior construction of so simple an affair as the object shown; however, if the interior construction is in the least elaborate this method is by no means satisfactory. If an interior construction be represented by a number of hidden lines which *cross* each other, the drawing becomes so vague as to be almost unintelligible. For this reason a substitute method has been devised for showing any interior or hidden construction. According to this method it may at any time be imagined that a *cutting plane, parallel* to one of the *coordinate planes,* can be drawn in any position, *cutting away* such portions of the object as *will expose any other parts one may wish to see.* Ordinarily these planes will be found to pass thru some axial line of the object, Fig. 18; however, if desired, they may be imagined drawn elsewhere, Fig. 19. This process of sectioning is purely imaginary and may be represented on only one view of a two or three view working drawing, the other views representing the object unsectioned by any such plane. The process of sectioning is strictly utilitarian; i.e., one should section *only* objects whose construction can be *more clearly explained* by this process than otherwise.

Certain terms applying to sections are sometimes confused from the fact that they may apply either to the drawing or the object. These terms are quarter section, half section, and full section. The confusion ordinarily comes between the terms quarter and half section. From Fig. 20, it is seen that when one-quarter of the object is removed one-half of the drawing will be found sectioned. Likewise if the entire front or half of the object were removed the drawing would be full sectioned. Hence the term quarter section will then, of course, be entirely discarded, as it can refer only to the object.

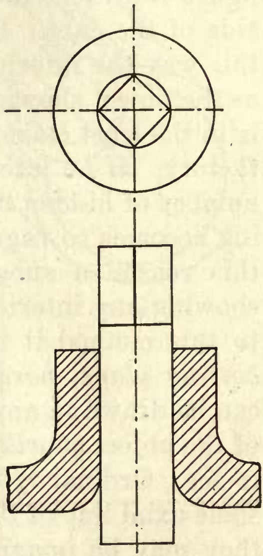


Fig. 21

Solid cylinders. The draftsman should keep in mind the fact that there is but one thing to be gained in sectioning, i. e., to show more clearly the *interior construction* of any piece of machinery; if the section does not accomplish this purpose it is just so much wasted labor. This point refers particularly to *solid cylinders,* e. g., *shafts,* Fig. 21, *bolts, screws,* etc., which should never be sectioned.

Interpolated or Revolved Sections. In such cases as are shown in Fig. 22, with respect to *rims* and *spokes of wheels, standard construction iron,* etc., sections known as *interpolated or revolved sections* are given to show the cross-section of the material at certain places. These sections are obtained by passing planes perpendicular to the axis of the piece to be sectioned and revolving this plane 90° about the center line of the section thus cut.

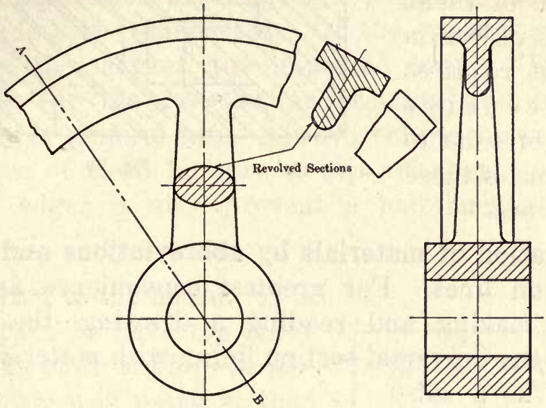


Fig. 22

Section thru spokes. Whenever the *cutting plane* passes thru spokes of wheels as is the case shown in Fig. 22, the cross hatching is put in as if the *plane* had been passed on the line AB.

Section lines. *Indication of material by variation in section lines.* It is the custom in many shops to indicate the material of which a piece of machinery is to be made by using a characteristic section line for any parts of that piece which have been sectioned, Fig. 23. There are some apparent disadvantages in this, however, for there is at present no universal standard system of section lining. Some shops use one characteristic for *brass, wrought iron,* etc., and others a radically different characteristic. Furthermore, unless one uses these section lines constantly or has a chart of them with him always, he may find it quite difficult to remember some of them. A third objection is that it requires an excessive amount of time to draw some of these section lines.

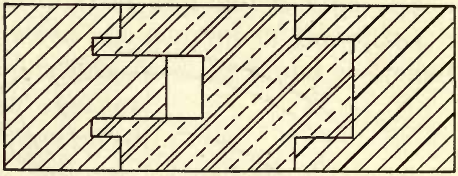
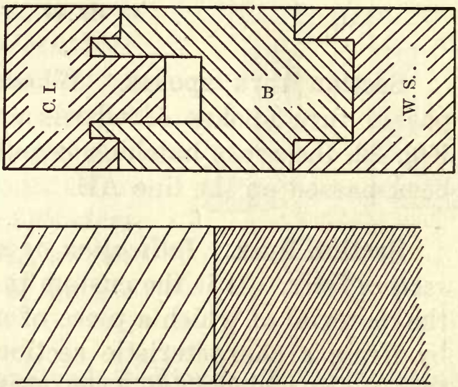


Fig. 23

Indication of materials by abbreviations and universal section lines. For greatest convenience and ease, both in making and reading a drawing, the writers approve the universal section lining with *material* abbreviations as a substitute for the above system, i. e., the use of the standard section line now used for cast iron as the standard for all materials and the particular material of which the piece is to be made indicated by its characteristic abbreviation as shown in Fig. 24. These abbreviations are easy to remember and the section lines can be drawn rapidly.



Where necessary a variation in space between section lines may be substituted for a change in direction of lines

Fig. 24

TRACING

(45) **Tracing cloth** is a fine quality of cotton coated with a preparation which gives it a smooth hard surface and renders it transparent. Of the various grades of cloth on the market, the imported brand "**Imperial**" gives by far the greatest satisfaction and is recommended for general use. Always before making use of any piece of cloth be sure to rip off about 1/8″ of the *selvage* edge; it may prevent a bad buckling of the tracing.

Tacking to the board. It is best always to have the sheet of tracing cloth *slightly larger* than the sheet of paper so that the tacks used in pinning down the cloth may be placed *outside* the sheet. In tacking down the cloth, preferably with the *dull side up,* be sure to stretch very tight and tack firmly. See Fig. 25 for best order of tacking.

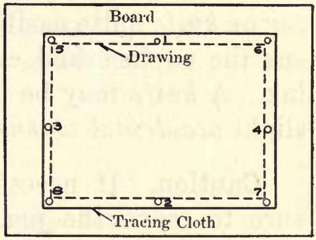


Fig. 25

Preparation of the surface of the cloth. Unless prepared in some way, the *surface* of the tracing cloth will likely take the ink very poorly, giving ragged and faded out lines. The cloth may be dusted or rubbed with **chalk** or preferably **magnesium carbonate**, which may be purchased at any drug store in 5-cent blocks, and then rubbed with a piece of linen.

Order of work. Unless one is sure of being able to finish the tracing of several views of a drawing before it is necessary to stop work, it will be found best always to *trace one view at a time, finishing* that view *before leaving work.* Tracing cloth has a decided tendency to stretch and warp, and it may be found most difficult to make old lines check with new if the tracing has been left standing for a day or more.

Erasing. In erasing, use the *pencil eraser* always in preference to the *ink eraser* or *knife.* It may require more time to erase a mistake; however, the cloth will be found in good condition after such erasing; while the *ink eraser* or *knife* quite easily roughens the surface and causes blots on application of new ink. A *knife* may be used to advantage in *scraping out* slight *accidental extensions* of *lines,* Fig. 26.

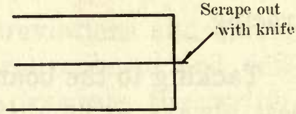


Fig. 26

Caution. If necessary to rule *across* ink lines, be sure to move the pen **rapidly.** If the pen is moving slowly the ink will likely follow down the old ink line to the T-square or triangle and cause a bad blot.

Weights of lines. The visible and hidden outlines are the heaviest lines on the drawing and should be slightly less than 1/32″ in width. This weight may be obtained by using a number 3 line on the adjustable graduated detail pen. All other lines on the drawing, i.e., dimension, auxiliary, center, and section lines, should have a weight of number one. Fig. 27.

Order of inking in tracing. In *tracing*, the following *order* should be observed for most rapid and accurate work.

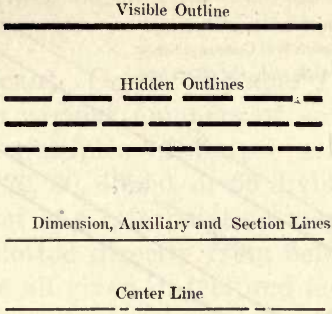


Fig. 27

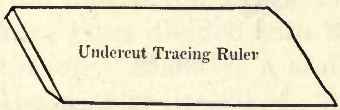


Fig. 28

1. Center lines.
2. Large circles and arcs.
3. Small circles and arcs with the bow pen.
4. Irregular curves with special curve.
5. Horizontal lines with the T-square.
6. Vertical lines with T-square and triangles.
7. Inclined lines in groups, e. g., 30°, 45°, and 60°.
8. Other oblique lines.
9. Dimension and auxiliary lines.
10. Section lining, dimensions and notes.

BEVELLED AND RAISED TRACING RULES

(46) For tracing, the two rulers shown in Figs. 28 and 29 are indispensable. With the *bevelled ruler*, Fig. 28, it is possible to rule across inked lines without any danger of blotting. The *raised ruler* of Fig. 29 saves an

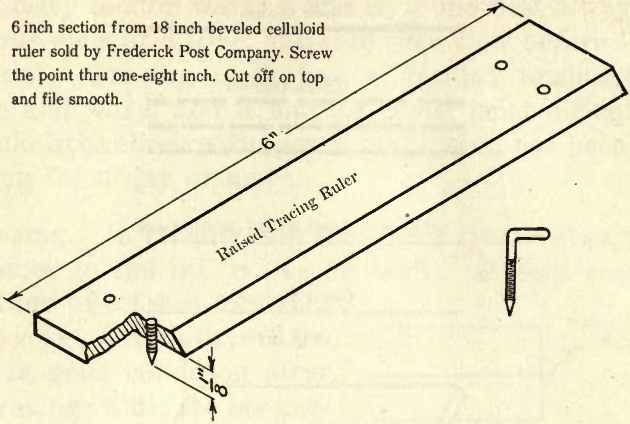


Fig. 29

immense amount of time, as it makes it possible to continue tracing no matter how many ink lines are still wet.

CONVENTIONAL LINES

(47) The conventional lines shown in Fig. 27 are standard and should be followed strictly. Concerning the *hidden lines,* it may be said that **no one thing except dimensions will add to or detract from the appearance of a drawing more than care or lack of it in the correct drawing of hidden lines, both as to the uniform length of the dashes and uniform space between dashes.** In *tracing,* follow strictly the *weights* given in the figure for these various conventional lines.

SCALES

(48) **Architect's scale.** The spaces representing feet on the *architect's scale* are divided into twelve equal parts, making it possible to draw, without any interpo-

lation, plans, etc., of objects whose dimensions are given in *feet* and *inches*.

Engineer's scale. On the *engineer's scale* the *inches* are divided into various numbers of subdivisions, these numbers being multiples of ten; i. e., the *inches* are divided into 10, 20, 30, 40, 50, or 60 divisions. By use of this scale without any interpolation maps may be made and drawings plotted directly from field notes in which the distances are all given in *feet* and *tenths* of *feet*.

Mechanical engineer's scale. Recently a scale has been placed on the market on which the spaces representing inches have been divided into halves, quarters, eighths, sixteenths, etc. Likewise a scale that combines all of the three scales just described. Mechanical engineers will find it to their advantage to own one or both of these.

Scale versus size. A drawing made to such a size that **one-half inch** on the *drawing* equals **one foot** on the *object* drawn, is said to be made to **one-half scale.** However, if the drawing be made so that **one-half inch** on the *drawing* represents **one inch** on the *object* the drawing is said to be made **one-half size** or to a **scale** of **½″** to **1″**.

CHAPTER 5

FASTENERS

(49) In every field of construction the builder finds it necessary to hold the component parts of the whole together by means of fasteners. Among the numerous kinds and varied shapes of fasteners, several are of such universal importance that the draftsman as well as the mechanic must be entirely familiar with the method of manufacture and manner of representing them on drawings.

Among others, rivets, keys, bolts and screws are to be specially noted. The several kinds of rivets with their customary conventional representations will be found in the appendix. Brief mention is made of the common standard keys in Art. 59. The greater portion of this chapter will be devoted in main to the most widely used fasteners, Bolts and Screws.

THREADS

(50) **The Helix.** The helix is a mathematical curve often wrongly termed the Spiral. It is generated by moving a point on any surface of revolution, around and along the axis of revolution. The motion of the point in both directions is generally uniform but may be variable in either or both of its motions. Thus we may have cylindrical, conical, spherical and many other forms of helices. On Bolts and Screws the thread is almost always a cylindrical helix. For special purposes the

thread may be a conical helix. The threads on water pipes and their connections are of this class. **Fig. 1** shows the geometric method of constructing a cylindrical helix, which form will always be understood when the term Helix is used. The distance (x) is called the **pitch** of the helix and may be assumed at will. In constructing the helix the pitch distance is divided into the same number of axial divisions as is the projected circle.

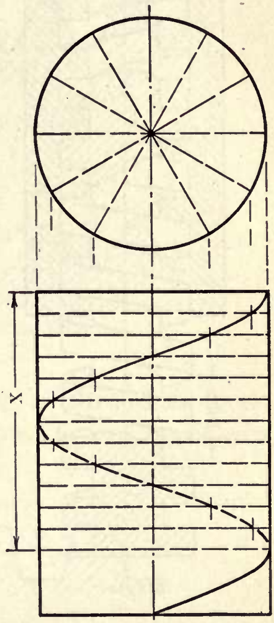


Fig. 1

From a mathematical standpoint, a thread is simply a *helix cut around and into a solid cone or cylinder.*

THREADS CLASSIFIED

(51) **V and Square threads.** Threads may be divided into two general types or groups, called **V** threads or **Square** threads according to the shape of the tool used in cutting them. Each of these groups may be further classified as **Single, Double, Triple** threads, etc. This latter classification depends upon the number of separate threads that are turned on one bar of metal. All threads are in general Single threads except in cases where rapidity of motion is required without a corresponding increase in coarseness of thread. Some ex-

amples of the foregoing mentioned threads are shown in Fig. 2.

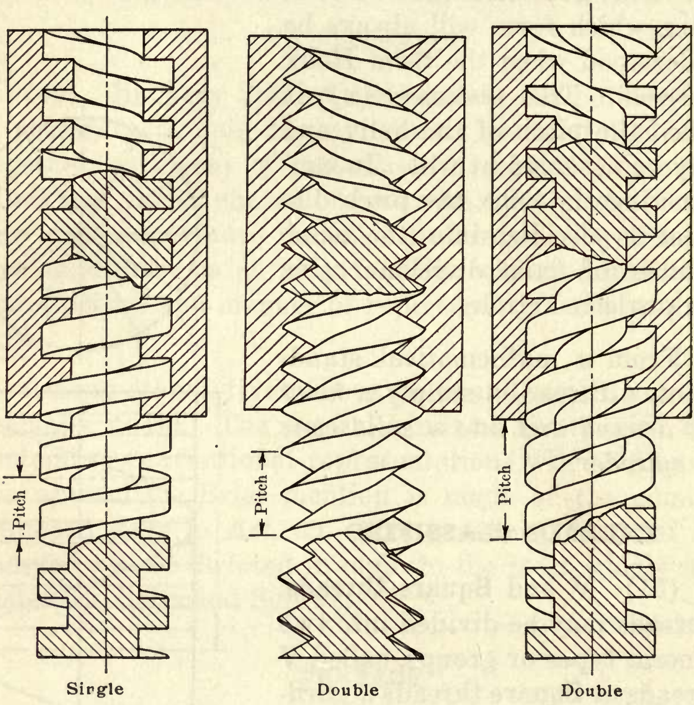


Fig. 2

V Threads. The V thread is the usual thread found on bolts and screws. It derives its name from the resemblance of its profile to the letter V. There have been devised numerous modifications of this thread intended to make it stronger and more durable and in some instances to fit special classes of work. Fig. 3 shows the profiles of some of these modified V threads. Of these several types the U. S. Standard (Seller's) thread is the most used in this country. Sizes and dimensions for this class of threads will be found in the Appendix.

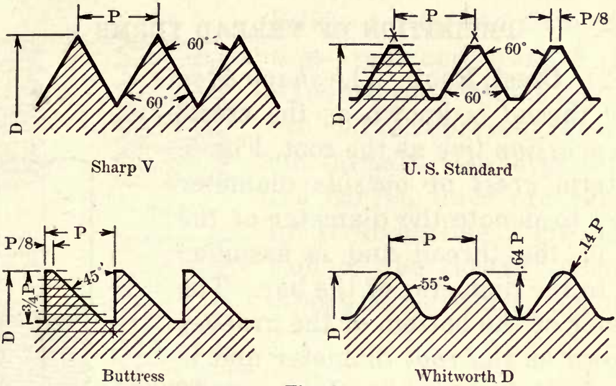


Fig. 3

Square threads. In cases where a thread is constantly being drawn or loosed or where heavy loads are

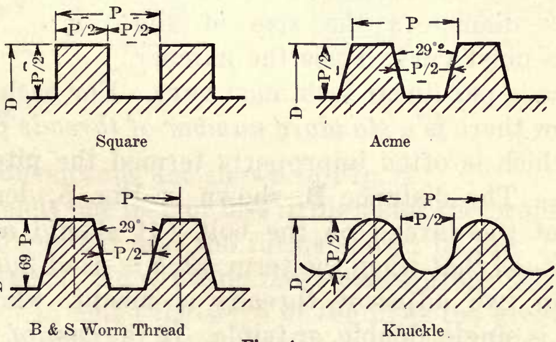


Fig. 4

to be lifted, the square thread finds an important place due to the reduced friction over the V thread. This thread finds a further field of usefulness in transmitting motion. As with the V thread, many modified forms have been devised. Fig. 4 illustrates a few of these forms.

DEFINITION OF THREAD TERMS

(52) **Crest, Root.** The *sharp edge* of the thread is known as the **crest;** the *depression line* as the **root,** Fig. 5. The term *crest* or *outside* diameter is used to denote the diameter of the crest of the thread and is assumed equal to the diameter of the bar. The diameter of the bottom of the grooves is known as the *root* diameter and is approximately equal to the crest diameter of the nut or the diameter of tap drill.

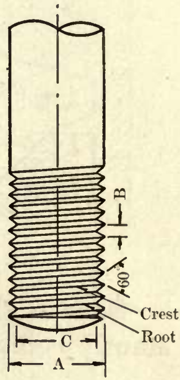


Fig. 5

Pitch. For bolts and screws of various diameters the size of the threads must vary, hence the number of threads per linear inch must vary. For each size bolt or screw there is a *standard number of threads per linear* inch which is often improperly termed the **pitch** of the thread. The distance **B,** shown in Fig. 5, denotes the *pitch* of the thread on the bolt. It should always be understood that when the term *pitch* is used the distance between two adjacent threads is meant, whether the thread is single, double, or triple. In the case of the latter two threads the term **lead** is used to denote the distance between *crests* on the same **helix.**

CONVENTIONAL REPRESENTATION OF THREADS

(53) As noted above, the projections of threads on planes parallel to the axis of the threads are curved lines. As each thread requires two helices for its complete projection—root and crest, Fig. 2—standard conventions have been evolved to represent the different threads. On large threads the curved lines are replaced by straight lines; the projection of the thread remaining otherwise the same. Examples

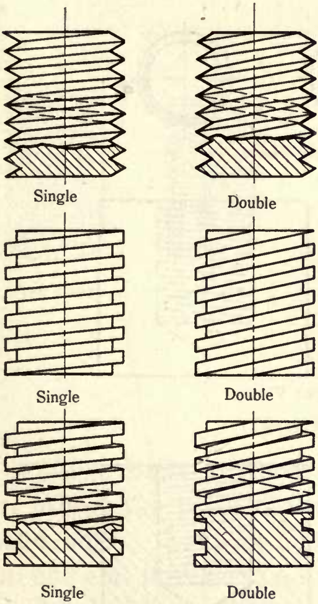


Fig. 6

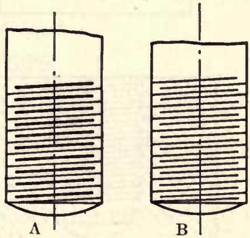


Fig. 7

of these conventions are shown in Fig. 6.

On threads one inch or less in diameter the profiles are omitted altogether and the forms shown in Fig. 7, A, B and C are used. In drawing these conventions care must be used not to make the slope of the lines too great, one-half the pitch being right. The spacing may be done by eye but should conform in a relative way to the number of threads on the several bolts or screws on a drawing.

Light pencil guide lines should be ruled limiting the length of the short heavy lines which should be equal to the root diameter of the thread. When threads are to be shown as invisible lines, the convention as shown in

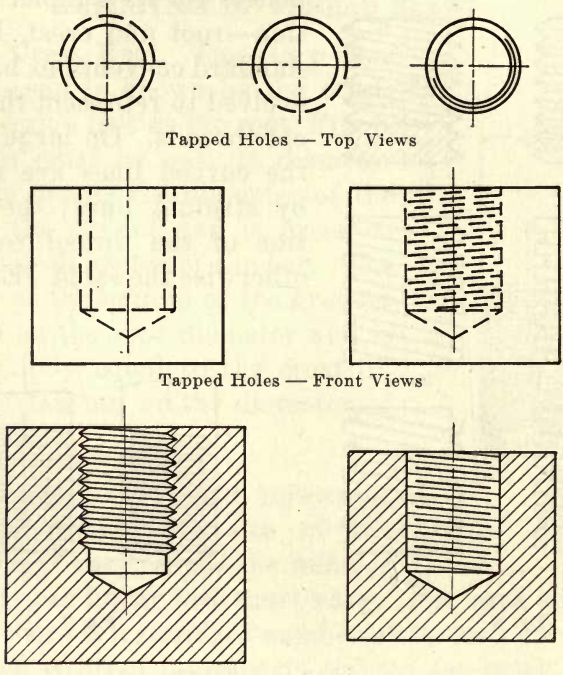


Fig. 8

A Fig. 8 is recommended. Altho possessing no appearance of a thread it is easy to construct and is universally understood by mechanics. Fig. 8 represents the conventional way of showing threads in *tapped holes,* the largest diameter being known as the diameter of the thread. In some instances threads may be made left handed.

Care should be taken to show such threads by the proper slope of the lines. Also attention is directed to the change in direction of slope for threads in sectioned parts. These variations may be understood more fully by reference to Fig. 9.

Conventional Representation of Screw Threads

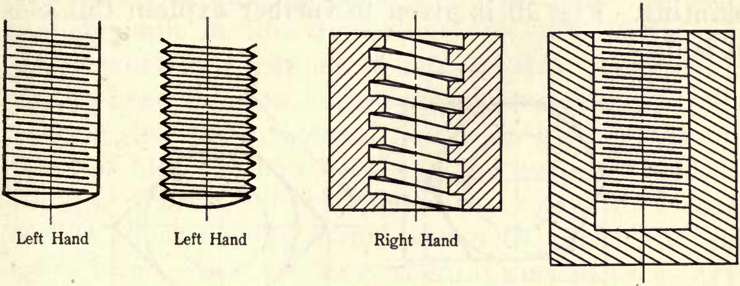


Fig. 9

BOLTS AND NUTS

(54) **Bolts.** There are three distinct classes of bolts in use at the present time called **carriage, machine,** and **stud** bolts. Each is made from a rod of iron, threaded on one end to receive a nut, and, with the exception of the stud bolt, having the other end shaped into some form of head.

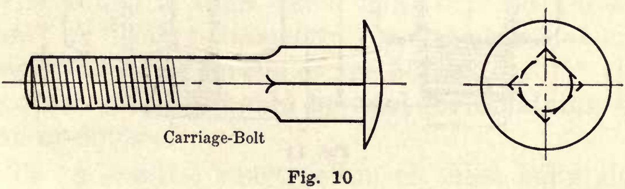


Fig. 10

Carriage bolts. A carriage bolt may be defined as a bolt with an oval head; its shank is squared from 3/8″ to 3/4″ under the head, the side of this square being a little larger than the diameter of the bolt. This bolt is used in woodwork and when drawn into a hole the square under the head takes a grip in the wood and prevents turning while the nut is drawn. The nut being thinner than the ordinary nut the whole effect is to give a more finished appearance to this class of work, especially after painting. Fig. 10 is given to further explain this class of bolts.

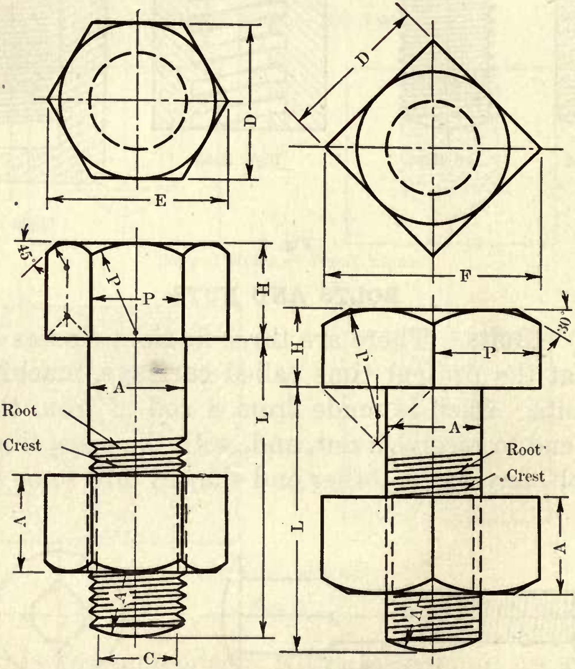


Fig. 11

Machine bolts. Machine bolts are divided into a number of classes, each class being named either from its peculiar *shape* or its distinctive *use*. The dimensions of the several parts of all such bolts have been standardized, tables arranged, and the construction and size of every part of any particular size bolt is perfectly definite.

Hexagonal and square-headed bolts. Inasmuch as these two classes of bolts are usually dealt with in the same table of dimensions, it will perhaps be as well to include both in this discussion. In Fig. 11 is shown the conventional manner of representing hexagonal and square-head bolts in a mechanical drawing. It will be noticed that the *hexagonal* bolt is so placed that *three* faces of both the bolt *head* and the *nut* are visible and the *square* head bolt is so placed that *two* of its faces are visible. This placing should be strictly adhered to, especially in machine sketching where it may be necessary to show the kind of bolt by only one view.

Likewise it will be seen that on both bolts the outer corners of the heads and nuts have been ground or turned off until the face of the head and nut is a circle tangent to the hexagonal or square limits of the head or nut. This bevel on the head or nut is called the **chamfer** of the head, etc.

In constructing the *end view* of any bolt the *chamfer circle* is first drawn (the diameter of this chamfer circle will be found in table under head of *"Distances Across Flats"* or *"Short Diameter"*) and the *hexagon* or *square* circumscribed by means of the 30°x60° or 45° triangles. **No other method should be used for obtaining the hexagon or square.**

The geometric construction of these bolts should be entirely familiar to the draftsman, and Fig. 11 should be thoroly studied and mastered in every detail. Fig. 12 should also be consulted in this connection.

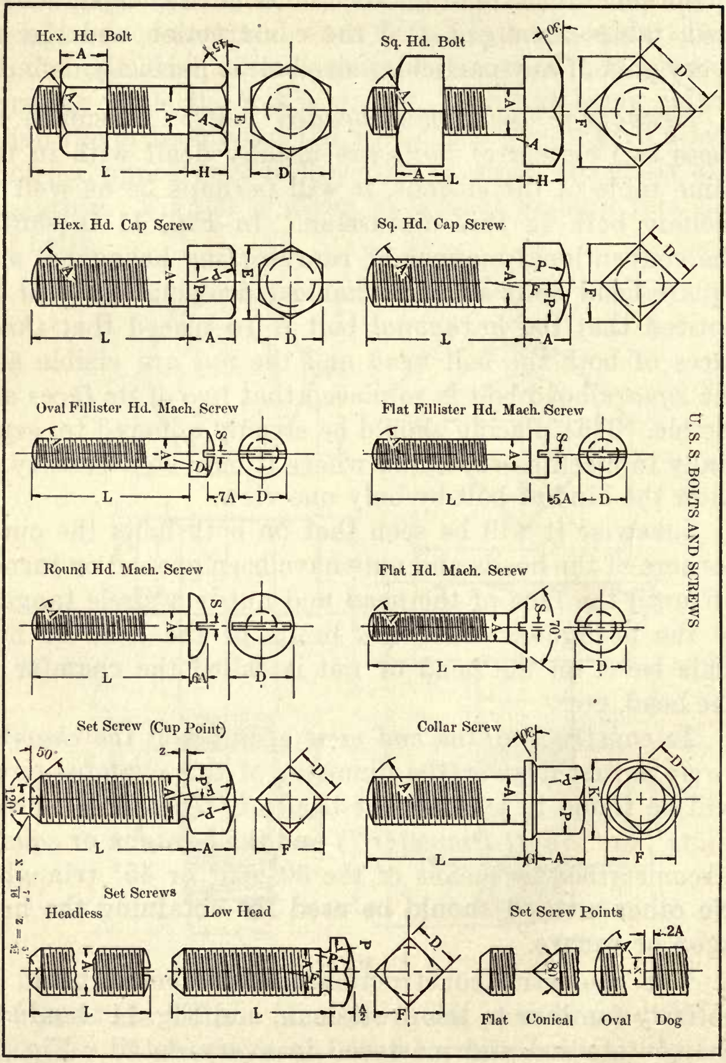

Hex. Hd. Bolt
Sq. Hd. Bolt
Hex. Hd. Cap Screw
Sq. Hd. Cap Screw
Oval Fillister Hd. Mach. Screw
Flat Fillister Hd. Mach. Screw
Round Hd. Mach. Screw
Flat Hd. Mach. Screw
Set Screw (Cup Point)
Collar Screw
Set Screws
Headless
Low Head
Set Screw Points
Flat
Conical
Oval
Dog
U. S. S. BOLTS AND SCREWS

Fig. 12

Stud bolt. On account of the particular use and form of the stud bolt it deserves special mention. It has no head and is threaded on both ends nearly up to its center. In places where a headed bolt is impracticable the stud bolt is screwed into the tapped hole in the piece of metal; the part to be clamped in place is then slipped on the projecting end and an ordinary nut used to draw the piece tight. The bolt thus serves the second purpose of being a guide in assembling which makes it almost indispensable in places where machine parts are removed and replaced very often. Fig. 13 illustrates this important bolt.

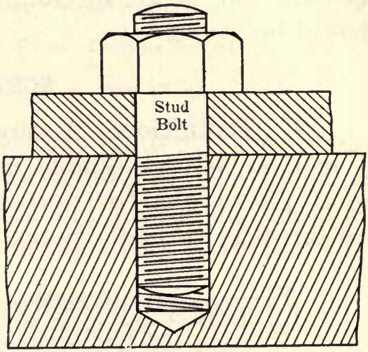


Fig. 13

Nuts. A *carriage* or *machine bolt nut* may be defined as a *square* or *hexagon* of *steel* or *wrought iron* of any desired thickness with a *threaded hole thru* the *center.* They need no classification, since they differ only in shape, thickness and finish. They may be square or hexagonal, very thick or quite thin, and if rough they quite likely have been punched from sheets of wrought iron or steel, while the finished nuts have been cut from square or hexagonal bars of steel, Fig. 11.

DIMENSIONING BOLTS

(55) **Length, diameter.** The length of a bolt is always understood to be the distance from the end to

the under surface of the head. In placing a note on a drawing designating the size of bolt used, the diameter, length, and pitch of thread should be given in the order named, followed by the kind of bolt wanted; e.g., 1″x 4″x 8 thrds. per in. Fin. Hex. Bolt. If the bolt is to be a U. S. Std. bolt, only the length and diameter are needed. On large or long bolts the threaded length should be given.

SCREWS

(56) **Definition.** A screw may be defined as a *rod* of *iron* or *steel threaded* on *one end* and *containing* a *square, hexagonal,* or *slotted head* on the other by which the screw is turned. Screws are divided into four gen-

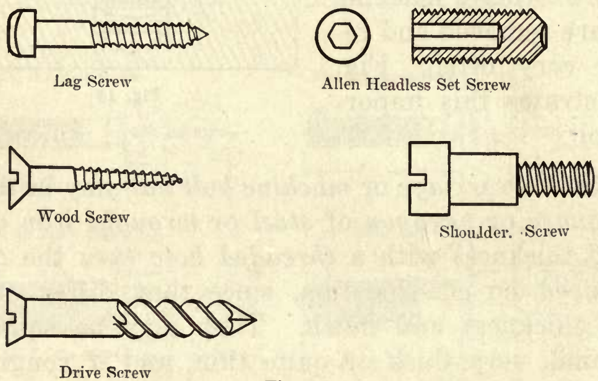


Fig. 14

eral classes—**wood, set, cap**, and **machine** screws. Figs. 12 and 14 illustrate some of the types most commonly used. Tables of dimensions may be found in the Appendix.

In listing screws on a drawing the method outlined in Art. 55 for bolts should be followed.

PIPE THREADS

(57) Many times the engineer is required to deal with plans in which water, steam or gas pipes are used. In order to make all connections water or steam-tight the threads are turned with a standard taper of 1″ to 16″. Care should be taken to specify this kind of thread when used on a drawing and to designate its size by giving the inside diameter of the pipe and not the outside diameter as is done on bolts and screws. Fig. 15 further illustrates this type of thread. Tables of pipe sizes and threads will be found in the Appendix.

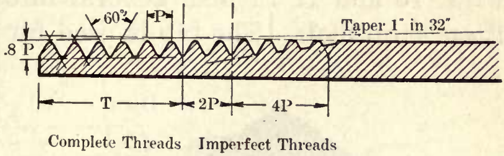
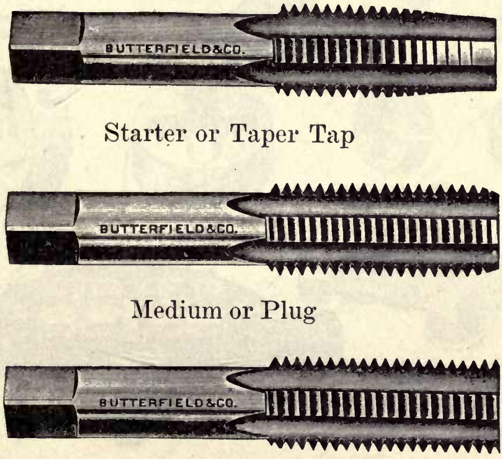


Fig. 15



Starter or Taper Tap

Medium or Plug

Finishing or Bottoming

Fig. 16

SHOP OPERATIONS

(58) **Taps and Dies.** The usual method of cutting V threads is by means of tools known as **taps** and **dies.** Figs. 16 and 17 furnish general information concerning these shop tools. The tap is used for cutting the threads

Dies.

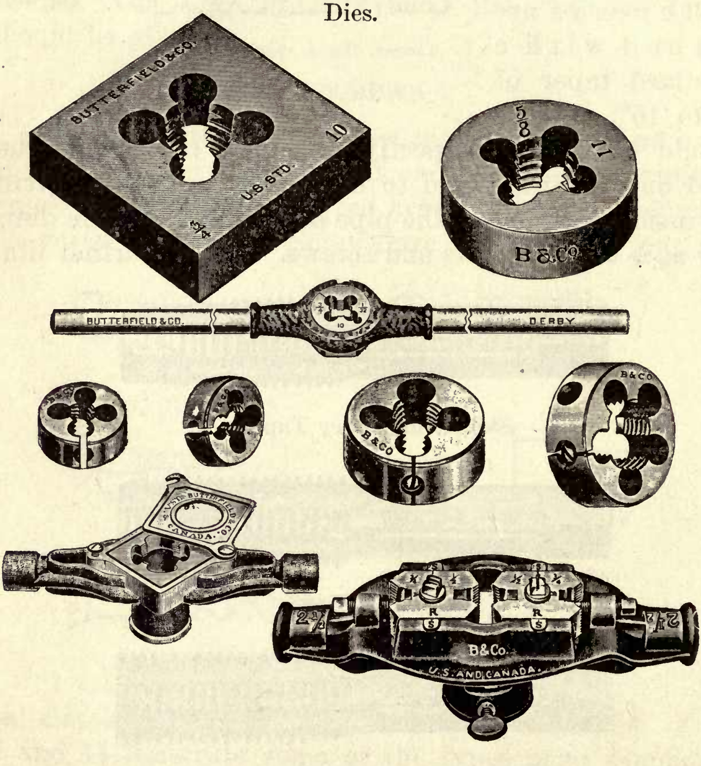


Fig. 17

in nuts and also for threading holes drilled in parts of machines. Dies are used for threading bolts and screws and other rods of iron not greater than 1″ in diameter.

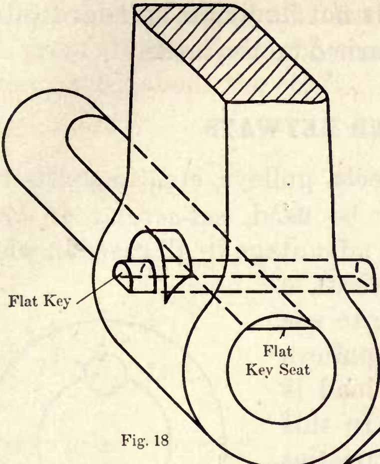


Fig. 18

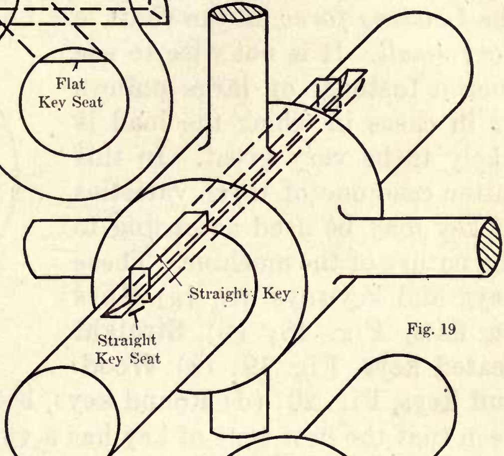


Fig. 19

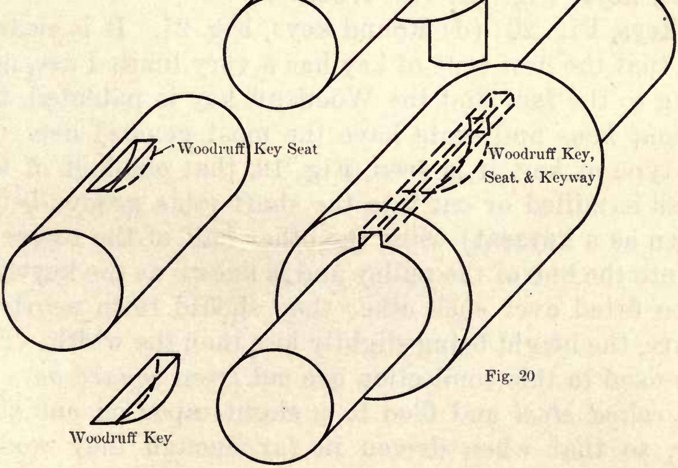


Fig. 20

Square threads, threads not having a standard pitch, and all large threads are turned on the lathe.

KEYS AND KEYWAYS

(59) In fastening wheels, pulleys, etc., to shafts two classes of fasteners may be used, *set-screws* or *keys.* Set-screws may be used to advantage in all cases in which the *twisting force* on the shaft is very *small.* It is not wise to use such a fastener on large pulleys or in cases in which the load is likely to be very great. In this latter case one of three varieties of key may be used according to the nature of the machine. These keys and keyways are (a) **Keys on flats,** Fig. 18; (b) **Straight seated keys,** Fig. 19; (c) **Woodruff keys,** Fig. 20; (d) **Round keys,** Fig. 21. It is clearly seen that the first type of key has a very limited use, and owing to the fact that the Woodruff key is patented, the *straight keys* and seats have the most general use. In this type of key, it is seen, Fig. 19, that one-half of the recess is milled or cut into the shaft (this groove being known as a **keyseat**) while the other half of the recess is cut into the hub of the pulley and is known as the **keyway.** When fitted over each other they should form nearly a square, the height being slightly less than the width. The *keys* used in this connection are cut from *square bars* of *cold rolled steel* and filed to a slight taper on one side only, so that when driven in far enough they wedge

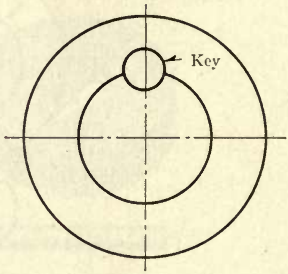


Fig. 21

between the hub and shaft, thereby preventing the pulley both from sliding along the shaft in either direction and from turning about the shaft.

CHAPTER 6

SHOP TERMS, TOOLS, MACHINES

Draftsman's Use of Shop Terms.

(60) Certain terms that are in common use in the workshop are used by the designer and draftsman in the form of a direction to the workman. Such words as "drill," "tap," "ream," "finish," etc., are shop terms directing the workman to perform the operation indicated. When these words are used on a drawing, the lettering should be so placed that there will be no confusion in determining to exactly what part of the object the term applies. Leaders should point to the part referred to if the meaning is not clear without them. If additional wording other than the simple term is needed, the English language should be used in such a way that the meaning of the note cannot be misunderstood.

Ordinarily, working drawings sent to the shop are made so complete that the same drawing will answer for the pattern-maker, blacksmith, and machinist. In this case, each workman uses only that part of the information on the drawing that applies to his work. Some large shops follow the method of making a separate drawing for each of these workmen, so that he will be supplied only with the dimensions and notes that apply to his particular work.

FINISH

(61) A casting or forging is in a rough state when it comes from the foundry or forge shop and if certain parts are to be machined, they are marked "**finish**" or simply

"f" on the drawing. The most convenient way of indicating that a surface is to be finished is to place the letter "f" across the straight line projection of the surface. In Fig. 1, the upper and lower faces of the block are to

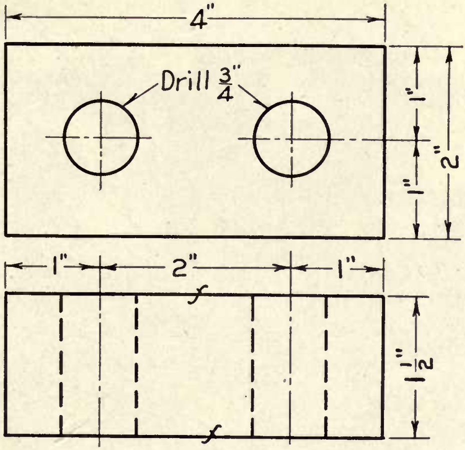


Fig. 1

be machined. Since the dimensions given on the drawing indicate the size of the finished object, surfaces marked with an "f" will indicate to the pattern-maker or blacksmith that allowance for the tool cut must be made on the casting or forging.

The note "f all over" placed under a detail drawing means that the entire surface of this part is to be machined.

The operations coming under the head of "finish" will in general be performed on lathes, planers, or shapers such as are shown in accompanying cuts.

MILL

(62) In the shop operation required in cutting *slots*, *grooves* known as **key seats,** also other similar operations, Fig. 2, a machine known as a **milling machine**

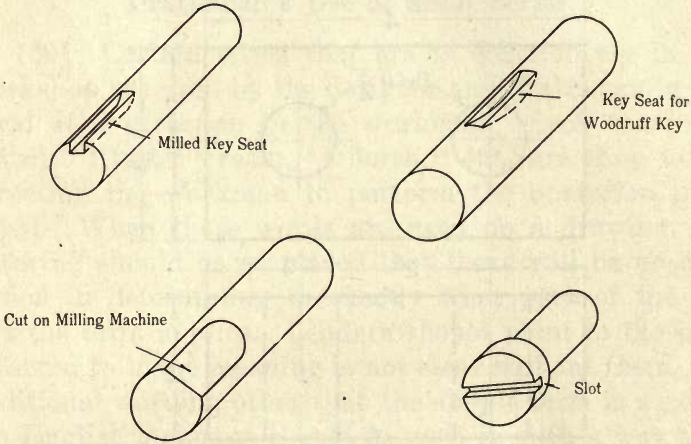
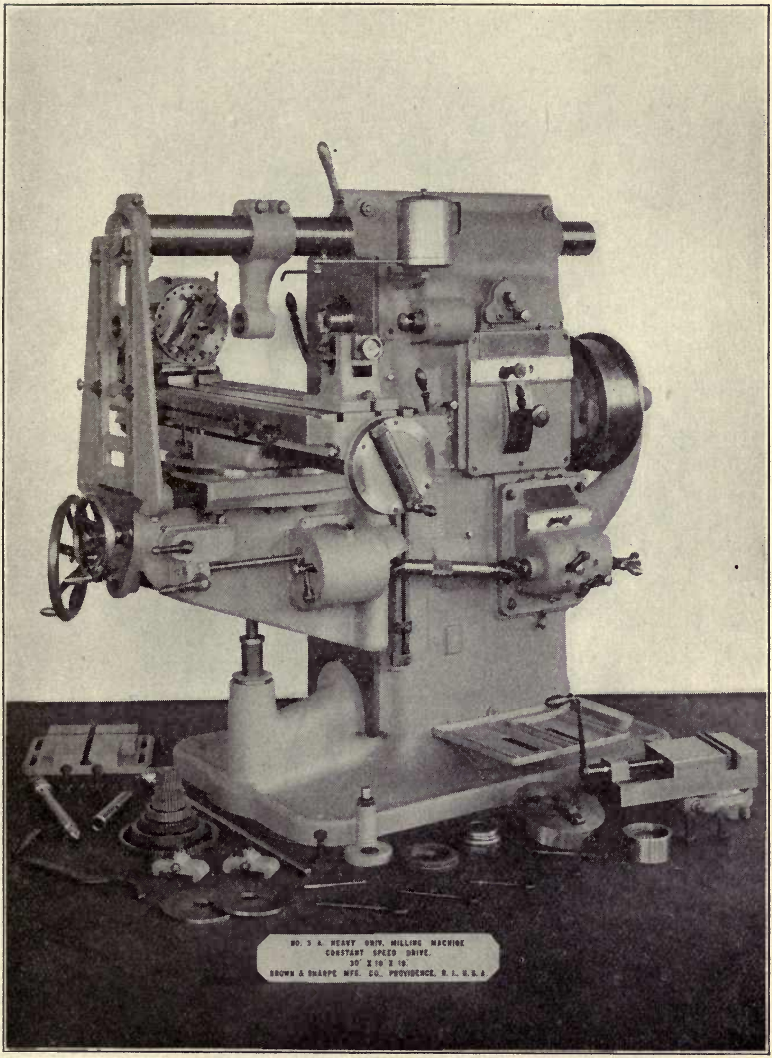
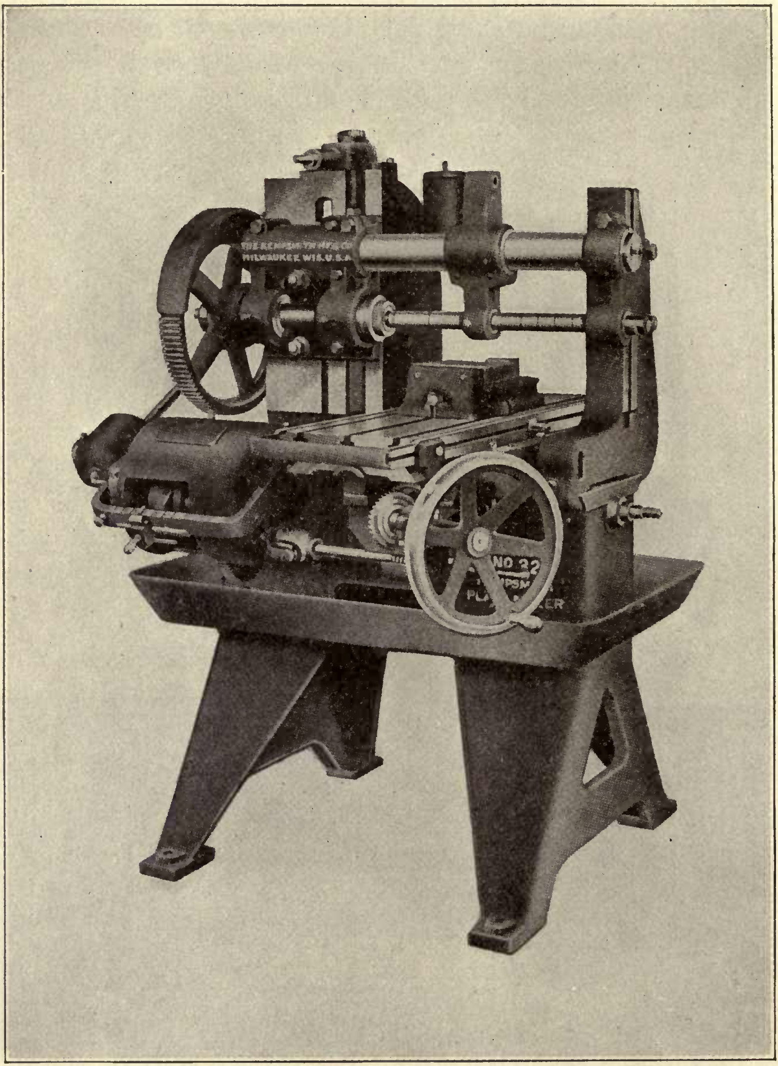


Fig. 2

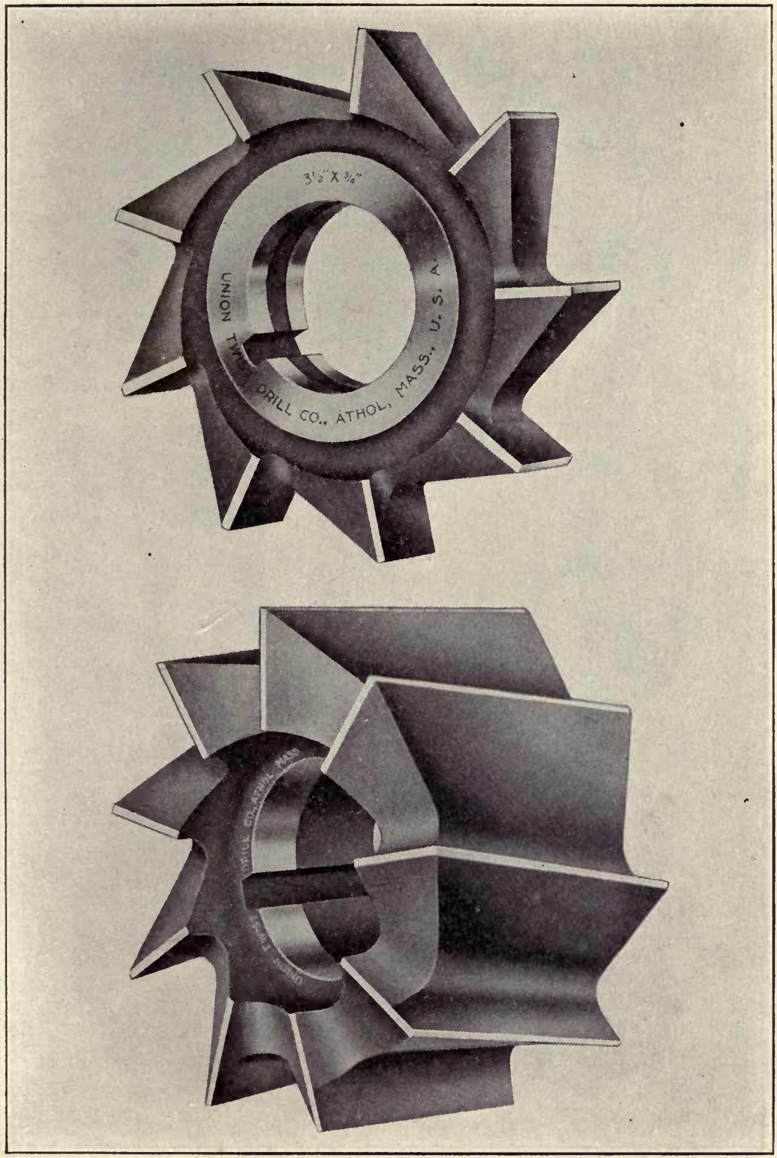
is used. The cutting tools resemble the common type of circular saw and operate on the same principle. As seen on pages 109 and 110, which are **horizontal milling machines,** the cutter is fastened rigidly to the revolving shaft or **arbor** while the piece of material to be machined is clamped to the table and the table moved, either by hand or automatically, slowly under the cutter, as a log is fed into the saw of a sawmill. For special work milling cutters of many odd designs are made, as seen on pages 111 and 112. The machine shown on page 113 is known as a **vertical milling machine,** the shaft or arbor in this case being *vertical.* To prevent vibration in the arbor of the horizontal machine (this vibration being



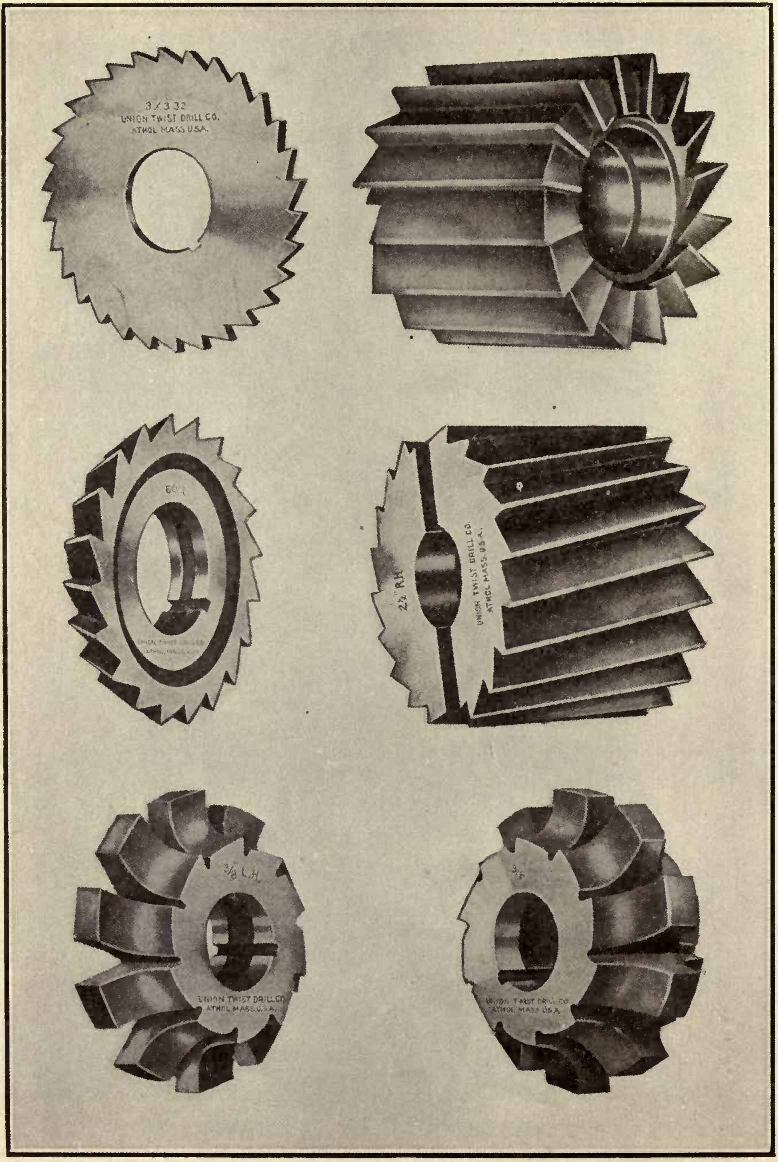
HORIZONTAL MILLING MACHINE



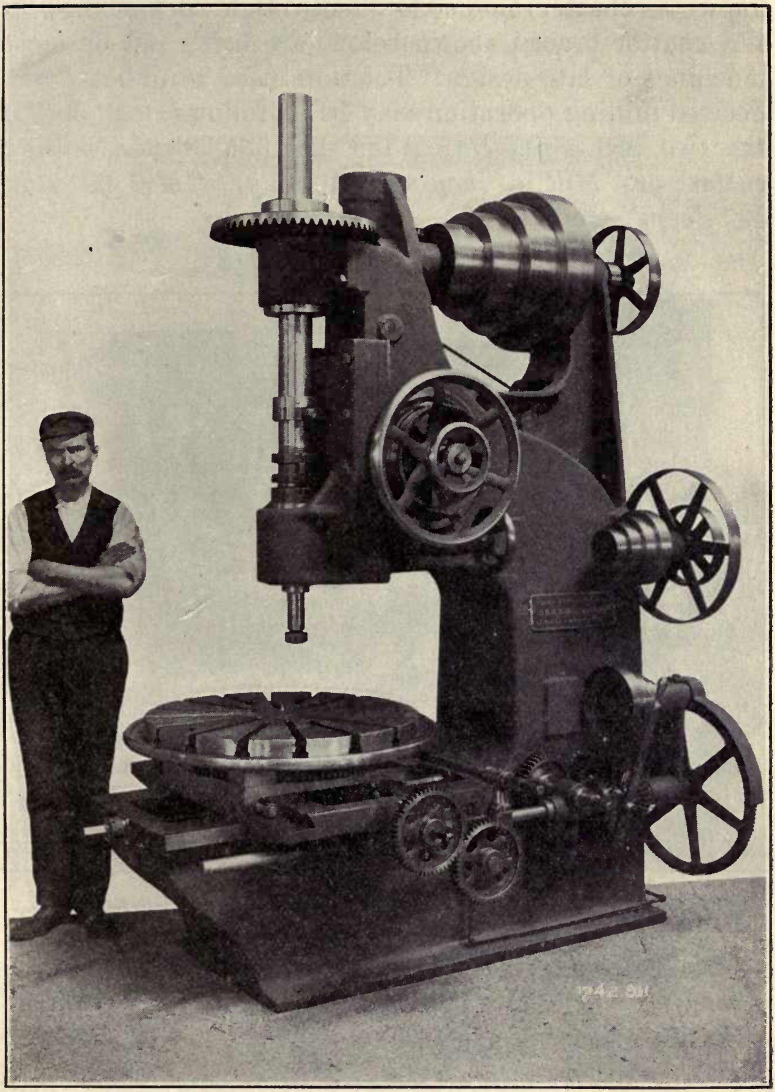
HORIZONTAL MILLING MACHINE



MILLING CUTTERS

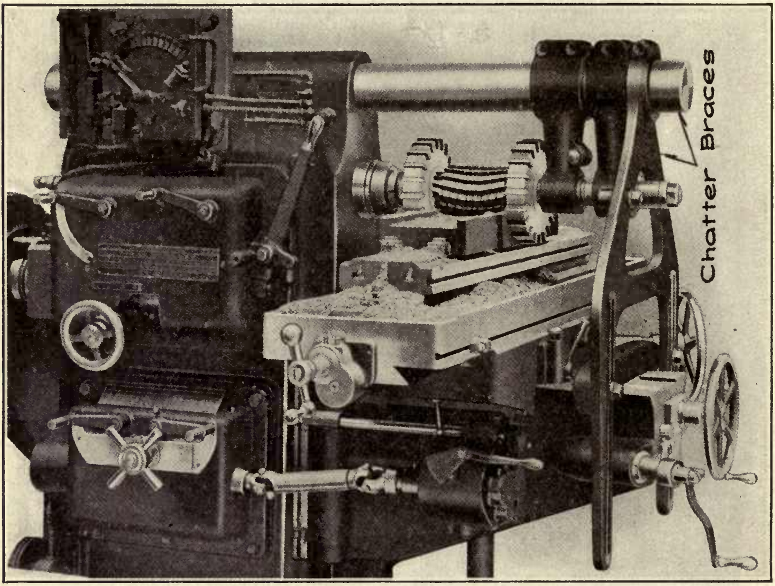


MILLING CUTTERS



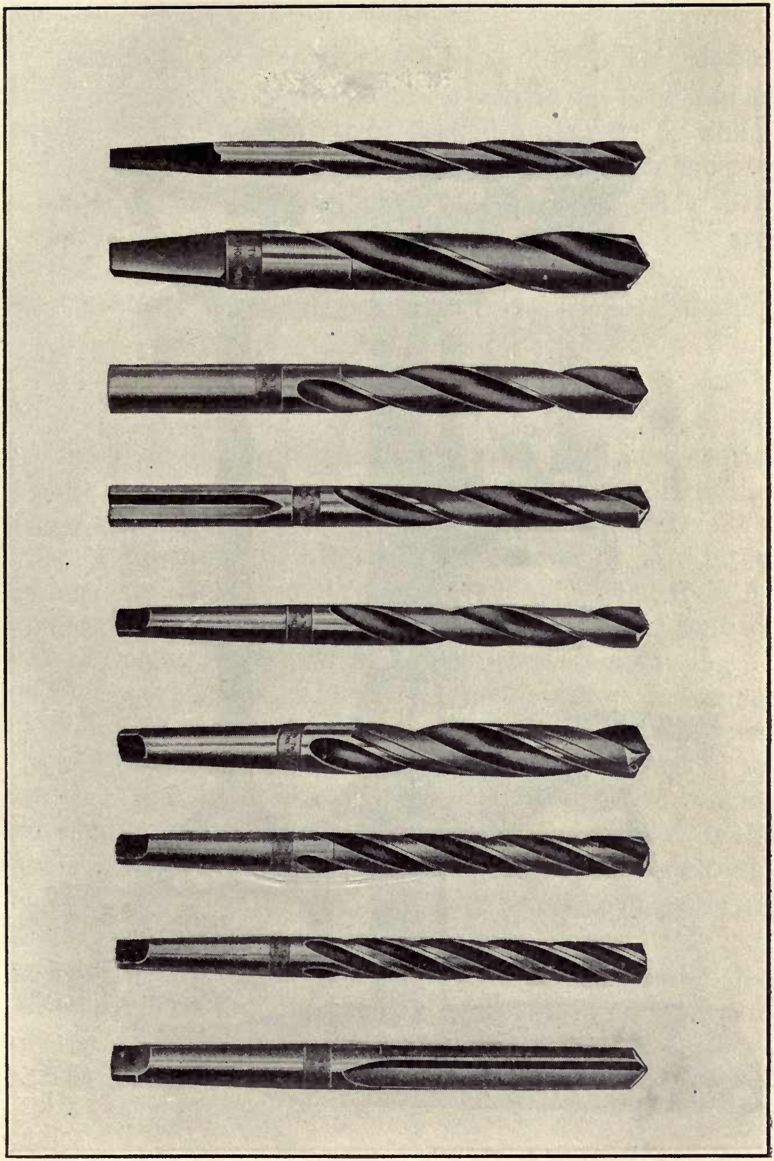
VERTICAL MILLING MACHINE

known as **chatter**) and consequent rough work of the cutter, **chatter braces**, shown below, are being put on most machines of late design. The note used to indicate any desired milling operation may be as follows: *"2″ mill"*; the two inches indicating the *diameter* of the *milling cutter;* or *"Mill ⅜″ key seat, 4″ long," "Mill ⅛″ slot, ¼″ deep,"* etc.

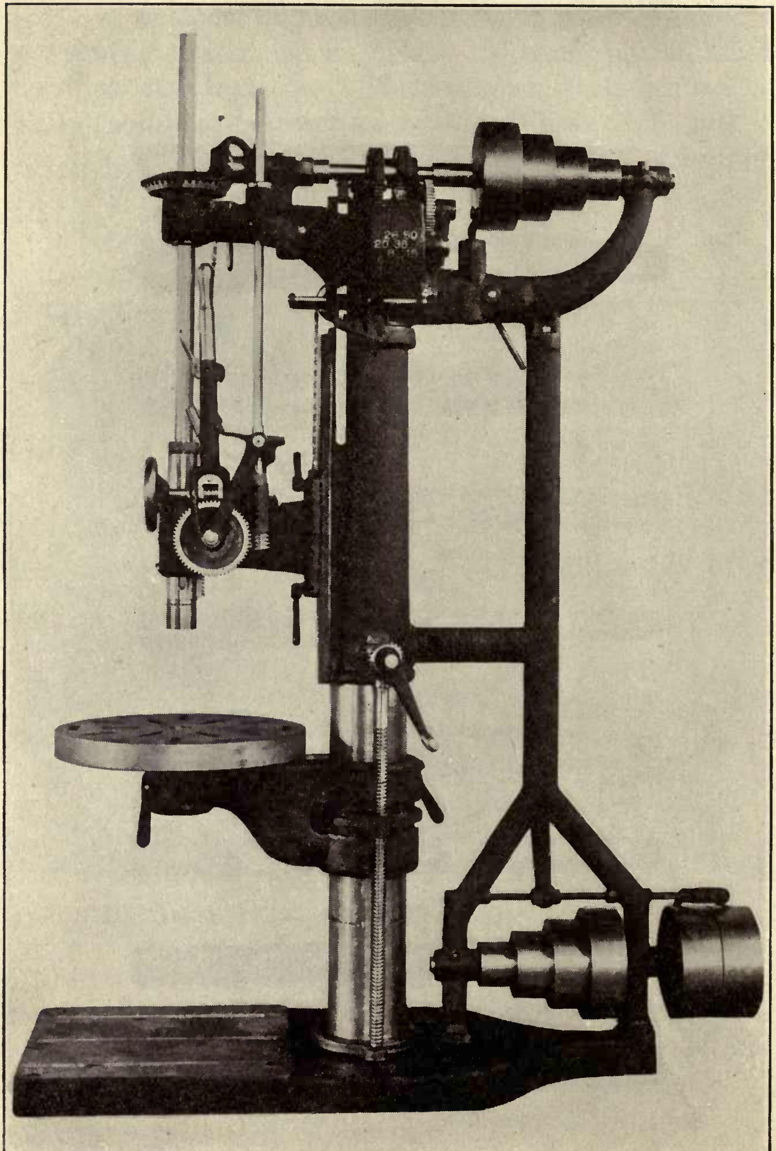


HORIZONTAL MILLING MACHINE WITH CHATTER BRACES

Since economy of time is a large item in shop work the designer will do well to study carefully the many possibilities of the milling machine. Next to the lathe and drill it is perhaps the most efficient machine in use.



TWIST DRILLS



DRILL PRESS

DRILL

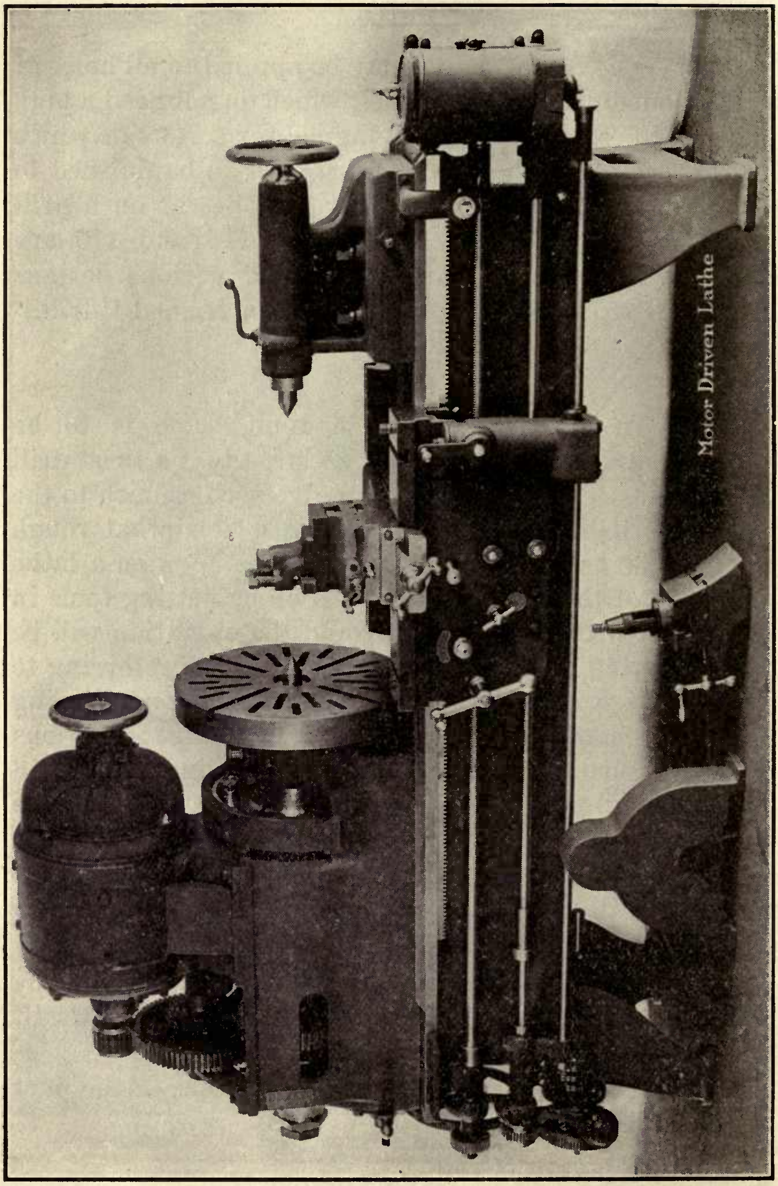
(63) The term **"drill"** may be applied to all holes of small diameter up to two inches, which do not need a high finish. Holes which are to be tapped for screws or which are to receive a bolt or which are later to be finished to a larger diameter with a reamer may be cut on a drill press with a twist drill. On pages 115 and 116 are shown twist drills and drill presses of various designs used in performing the shop operation termed "drill."

BORE

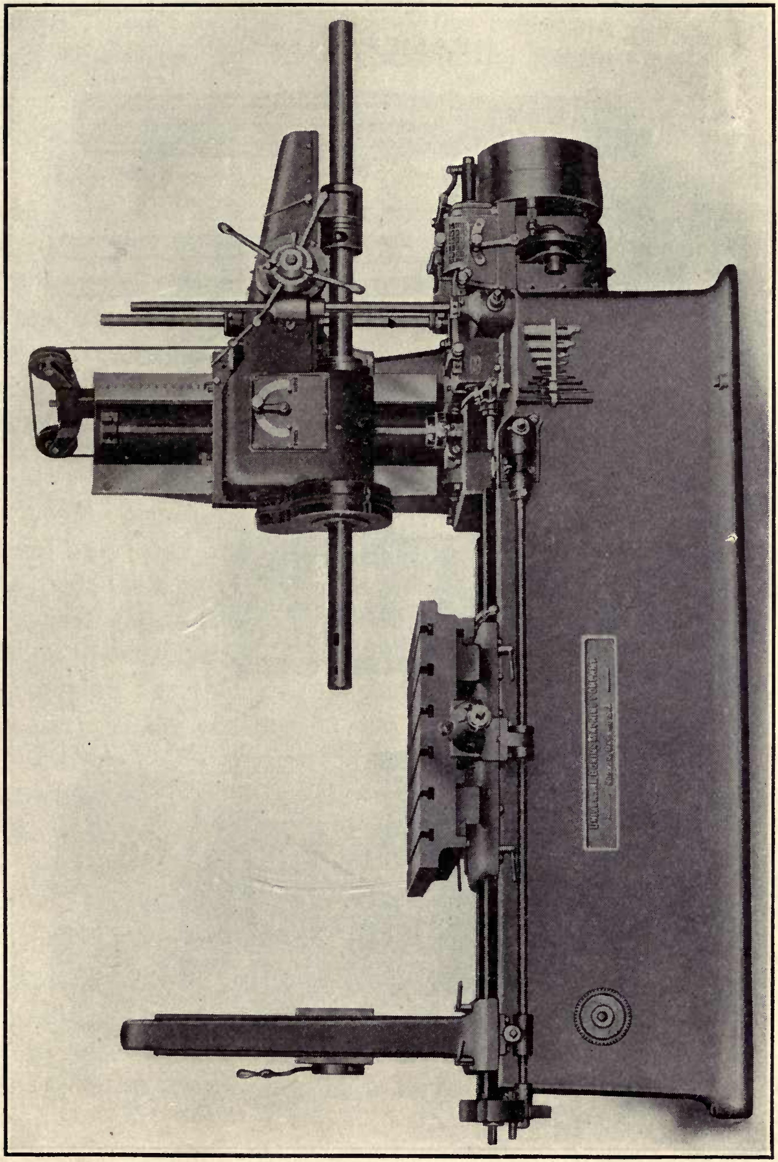
(64) In all cases where a round hole is to be machined and the hole is either so large that a twist drill cannot be used or it is desired to give such a finish to the hole as is impossible in the inevitably somewhat rough work of the twist drill, the work will be done on a lathe by means of the short boring tools or by cutting tools in connection with the boring bar and the operation will be termed **boring** instead of drilling. The note referring to such an operation is 7″ *bore,* etc., the *dimension* referring to the *diameter* of the hole. Such boring operations are performed on a lathe or boring machine, pages 118 and 119, and are ordinarily necessary on holes whose diameters are greater than two inches. Twist drills larger than two inches in diameter are not in very common use as it requires an extremely heavy drill press to operate them satisfactorily.

If a cylindrical part is to fit into a bored hole, the terms **"driving fit," "forced fit," "turning fit,"** etc., will tell the kind of fit that is required.

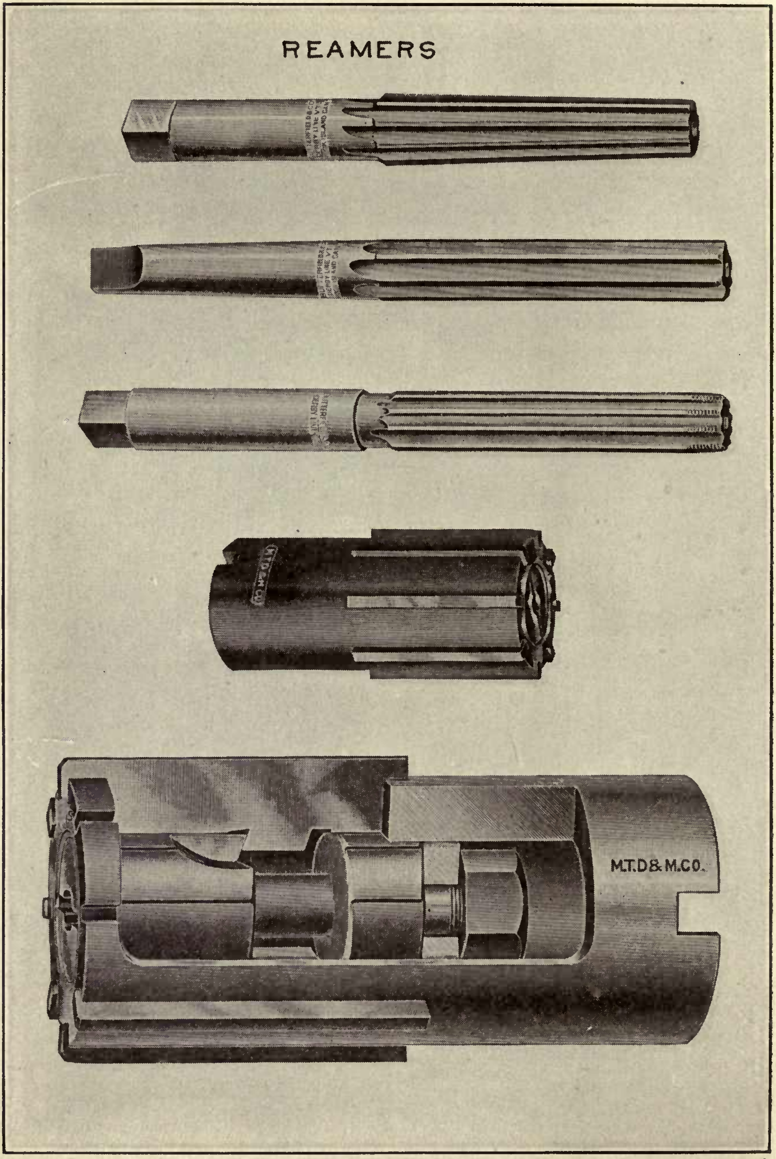
The dimension given will indicate the size of the part



MOTOR DRIVEN LATHE



BORING MACHINE



REAMERS

to be fitted into the hole and the necessary allowance for the desired fit will be made in the boring operation.

REAM

(65) Wherever a small hole is to be given a certain taper or is to be given a finish not possible with a twist drill or is to be cut to a very exact dimension, a tool known as a **reamer**, page 120 should be used and the term applying to such an operation is **ream.** This operation of course presupposes that a hole slightly less in diameter has already been cut with a twist drill, or bored on a lathe.

CORE

(66) The term **core** is used in connection with castings only and indicates that the hole referred to is to be produced by a **core** (*a hardened cast of sand of the desired shape and size*), which is placed in the mold when the casting is made. The pattern-maker must make provision for the core in the construction of the wood pattern of the casting.

"*Core* 1⅛″" means that a core 1⅛″ in diameter will be used in the mold. The cored hole will of course be as rough as the surface of a rough casting.

TAP

(67) The term **tap** applies to the shop operation required in cutting V threads in holes of comparatively small diameter; that is, less than one and one-half inches. The note used to indicate that a certain hole is to be threaded to a certain pitch is as follows: ½″ *tap* x 13 *pi.*

On pages 101 and 102 are shown a series of standard taps and likewise both bolt and pipe dies used in cutting V threads on bolts, pipes, etc.

TAP DRILL

(68) A *tap drill* is a *twist drill* of the common type, named a **tap drill** in this case because it has been used in drilling a hole which is to be threaded to receive a screw.

HARDEN, TEMPER, ANNEAL

(69) These are terms which have to do with the heat treatment of the machine parts in question and therefore will be interpreted by the workmen in the forge shop.

FILLET

(70) It is a well recognized principle of mechanics that a *break* is much more likely to occur in *sharp*

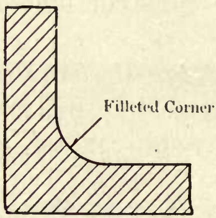


Fig. 3

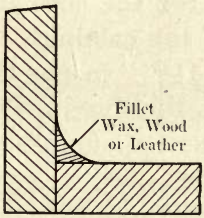


Fig. 4

corners of a machine than elsewhere, the corner seeming to furnish a starting point for the break. For this reason, and others which need not be mentioned, all corners found on castings are seen to be slightly rounded,

Fig. 3. This rounded corner is known as a **fillet**; likewise the *material* which is used to make this *fillet* in patterns takes the same name. In Fig. 4 is shown the method of making such filleted corners in patterns. The triangular piece shown is made of **wood**, shaped by driv-

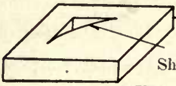


Fig. 5

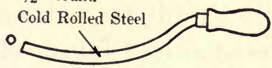


Fig. 6

ing thru a Die, Fig. 5, as *dowel pins,* or of **hard wax** rounded by a heated rod, Fig. 6, or it may be of **leather** which can be purchased in coils of any length. The leather fillets, of course, are most convenient for very irregularly shaped pieces. The radius of the arc of such fillets is quite generally ¼"; however, it is necessarily a matter of machine design and for very large pieces the radius must be greater than ¼".

BEARINGS

(71) **Brasses.** In certain types of machines it is desirable to use brass for bearings rather than the combination of lead and zinc and copper. Such bearings are ordinarily made in halves, constructed so as to permit of a slight adjustment, Fig. 7. These half bearings are commonly known as **brasses.**

Babbit. The alloy of lead, zinc and copper mentioned above is commonly known as **babbit.** The greater the amount of zinc and copper, the harder this compound is. Two of the material advantages of babbit for bearings are, that the metal is cheap, and such bearings can be easily replaced by a workman of but ordinary experience. Babbit lining is poured while molten into the cast iron casings with the shaft in place.

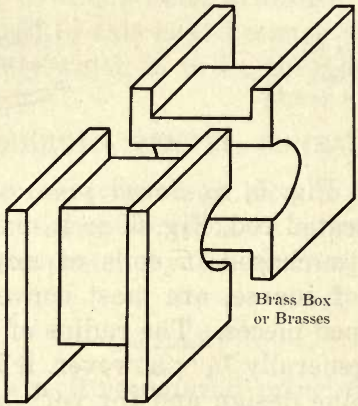


Fig. 7

CHAPTER 7

ISOMETRIC AND OBLIQUE PROJECTION

EXPLANATION OF PRINCIPLES

(72) If through a given point called the origin three lines be drawn at right angles to each other, as the three adjacent edges of a cube, we have the usual mathematical coordinate axes X, Y, and Z. These axes taken in pairs determine three planes, such as the three coordinate planes used in Chapter 3. If now an object with rectangular or square faces, for example a cube, be placed in the first angle, and be viewed in turn in the direction of the axes X, Y, and Z, the figure in each case will appear to be simply a square. These squares projected on their respective coordinate planes give, of course, the orthographic projections of the cube, and it should be remembered that the square seen, if the cube is viewed in the direction of the X axis, represents the entire object and not merely the face of it. Thus we see that one face only is visible, in general, in each view.

If now we imagine a line drawn in such a direction as to make equal angles with X, Y, and Z, for example, the diagonal of the cube, and view the object in the direction of this line, it is apparent that three faces will be visible, although now none shows as a rectangle, nor do we see any of the edges in their true lengths. However, all the edges of the cube parallel to axes X, Y, and Z are equally or proportionally fore-shortened if seen in the direction of this new axis, known as the **isometric axis**. The plane perpendicular to the isometric axis is known as the **isometric plane**, and the projection on this plane of any object viewed in the direction of the isometric axis is known as an **isometric projection.** The sheet of paper or blackboard may, of course, be conceived as the isometric plane, on which the projections of the three axes X, Y, and Z will be right lines making 120 degrees with each other and the projection of the isometric axis will be their point of intersection, Fig. 1. This point of intersection may also be termed the **origin.**

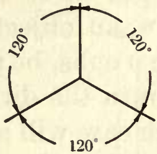


Fig. 1

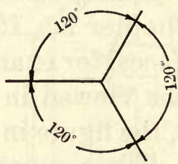


Fig. 2

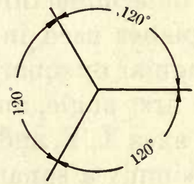


Fig. 3

DIRECTRICES

(73). The orthographic projections on the isometric plane of the three coordinate axes X, Y, and Z are known in the drawing as the **directrices**, and occasionally as the **isometric axes.** Since the coordinate axes make with each other equal angles, their projections (the directrices) also make equal angles (120 degrees) with each other. This being true, when it is desired to make any isometric projection, the directrices may be drawn immediately through any chosen point and at 120 degrees to each other. One of the directrices is usually taken vertical, Fig. 1; however, the arrangements shown in Figs. 2 and 3 are frequently used.

ISOMETRIC SCALE

(74) Since the coordinate axes are oblique to the isometric plane, their projections are shorter than the axes themselves. However, since each axis makes the same angle with the isometric plane, one inch measured on each of the three axes will project in equal lengths on the isometric plane. For all ordinary purposes, in

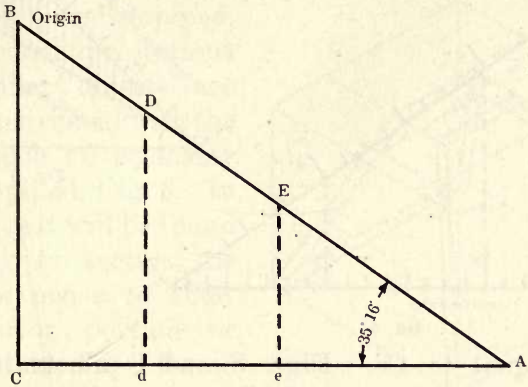


Fig. 4

making an isometric projection, it is more convenient to lay off the projections of lines which are parallel to X, Y, and Z equal in length to the actual lines. It is seen, of course, that the projection made with such measurements represents the object as being about fifty per cent larger than it actually is. Since the direct use of the scale in measuring these lines full length makes so much for convenience and only enlarges the view, this procedure is usually followed. If, on the other hand, it is desired that the projection be mathematically correct, the projection of all lines parallel to X, Y, and Z must be measured according to the isometric scale. Since each coordinate axis makes with the isometric plane an angle of 35° 16′, if we assume the hypotenuse AB of the right triangle, Fig. 4, to be one of the coordinate axes, BC the isometric axis, and CA the isometric plane, viewed edgewise, the isometric projection of any given length BE on the axis BA would project on the plane with a

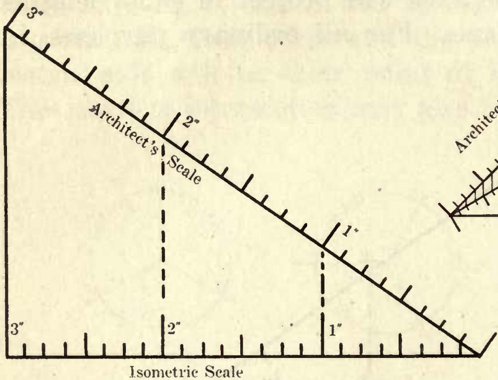


Fig. 5

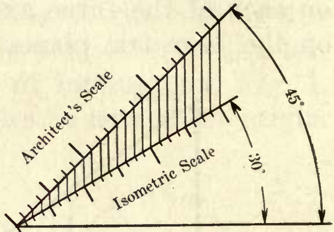


Fig. 6

length equal to Ce. Figs. 5 and 6 illustrate simple methods for obtaining the isometric scale.

(75) Problem 1. **To construct the isometric projection of any parallelopiped.**

Construction. Cube 2″ on edge, Fig. 7.

Thru point O are drawn the axes OB, OA, and OC, making with each other angles of 120 degrees. From O, along OA, measure with the isometric scale 2″; the same along OC and OB to points D, E, and F. OD and OE then represent the two adjacent sides of the base, and lines from D and E parallel to OE and OD complete the base. In similar manner the vertical faces DOF and

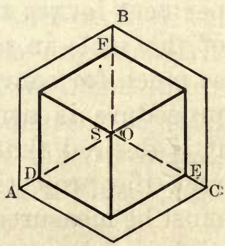


Fig. 7

FOE are completed; then draw the top base FS and finally the faces SD and SE.

IRREGULAR OBJECTS

(76) Inasmuch as all but a very small percentage of machine parts are either of rectangular shape or can easily be enclosed in such a box or parallelopiped, the isometric projections of irregular objects are easily constructed with the aid of such an enclosing parallelopiped, Fig. 8. In most cases it will be found necessary to section the object in order to show the interior portion or cross-section, Figs. 9 and 10.

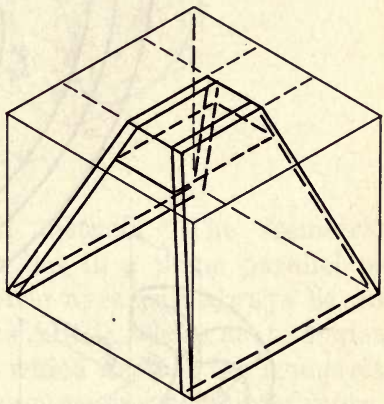


Fig. 8

CIRCLES

(77) Problem 2. **To construct the isometric projection of a circle**, Fig. 11.

8 point method. ABCD is the isometric projection of a square in which a circle is inscribed. On edge AB construct a square and inscribe in it a circle. Draw the horizontal diameter of this circle and diagonals of the square. The points of tangency of the circle with the square and the 4 points of intersection with the diagonals constitute the desired 8 points. If the diagonals of the parallelogram be drawn the isometric projections of these 8

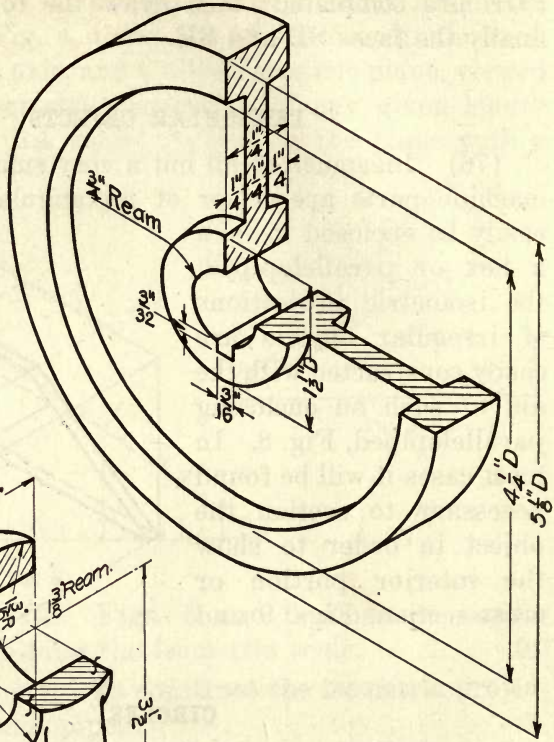

3/4" Ream
1"/4
3/32
3/16
1 1/2" D
4 1/4" D
5 5/8" D

Fig. 9

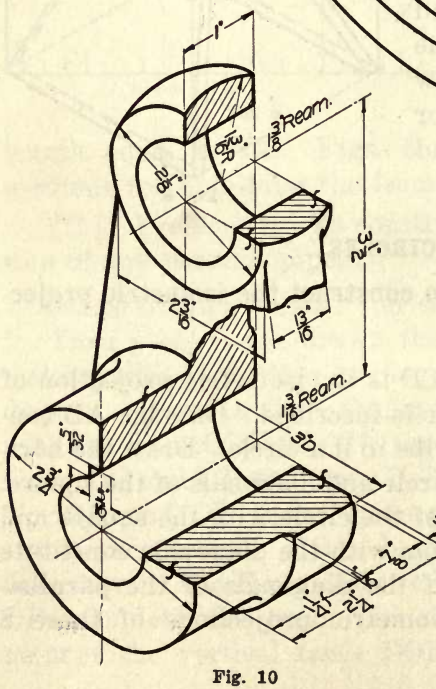

1"
1 3/8" Ream.
3 1/2"
2 3/8"
13/16
1 3/16" Ream.
3" D
5/32
2 3/4"

Fig. 10

points may be obtained as shown and the ellipse drawn thru them by means of the irregular curve.

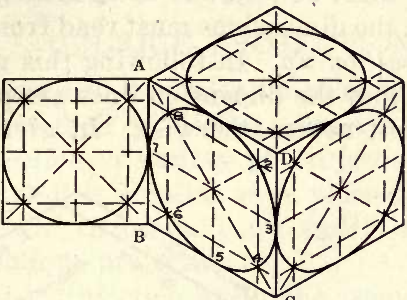


Fig. 11

Approximate mechanical method. The isometric projection of a circle which lies in a plane parallel to the plane of any two isometric axes will always be an ellipse inscribed in a rhombus ABCD, whose acute angles A and C are 60 degrees, and which itself is the isometric projection of the square circumscribing the circle represented. The ellipse may be approximated with satisfactory exactness if made of arcs of circles as illustrated in Fig. 12. From the obtuse angles B and D perpendiculars are dropped to the opposite sides. Then with radius R equal to DE and centers B and D the arcs HF and GE are described; with centers K and L, and radius r equal to LE, the small circles are described completing the approximate ellipse.

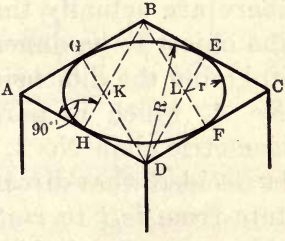


Fig. 12

DIMENSIONING

(78) In placing dimensions on an isometric drawing, the same rule must be followed as in orthographic working drawings; the dimensions must read from *left* to *right* or from the *bottom up.* In following this rule it will be found always that the dimension lines are parallel to the coordinate axes, **never** otherwise. In giving the *diam-*

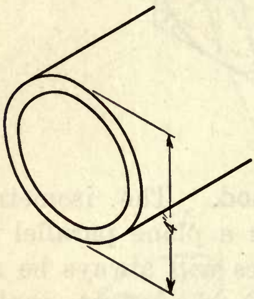


Fig. 13

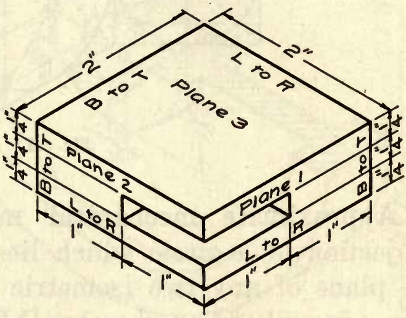


Fig. 14

eters of *circles* the method shown in Fig. 13 is preferable to placing the diameter directly on the isometric of the circle. On inspection of Fig. 14 it is seen that there are actually three faces of the object to be dimensioned and in giving the dimensions for face No. 1, which is parallel to the isometric plane No. 1, it must first be decided what directions constitute from *left* to *right* and from *bottom up.* The same thing must be decided for faces 2 and 3. In Fig. 15 is given a key which will be useful in dimensioning. In con-

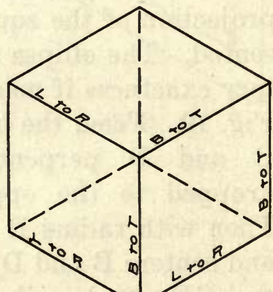


Fig. 15

nection with this key it will be necessary for the student, in placing dimensions, to decide merely to which face of this key his dimensions are parallel, Figs. 9 and 10.

OBLIQUE PROJECTION

(79) Inasmuch as circles are so rarely found in such positions that their projections are true circles in *isometric projection,* a variety of projection has been devised in which it is possible so to place circles that their *projections* are *circles* and are easily drawn. This is known as **oblique projection.**

In oblique projection as in the isometric projection just discussed, we have *one* plane of projection. The line of sight is *always* assumed oblique to the plane of projection. We may call this line the *oblique axis.* If two of the *coordinate axes* are placed parallel to the plane of projection and projected thereon by lines parallel to the line of sight, the projections will be unchanged in relation to each other. In projection the third axis will, however, be foreshortened and inclined to the other two at an angle other than 90°. This angle may be varied at will according to the angle of inclination of the oblique axis with the plane of projection, but is usually assumed at 30°, 45°, or 60° with the horizontal. These projections of the coordinate axes are called the *directrices.*

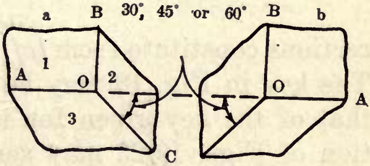


Fig. 16

DIRECTRICES AND CO-ORDINATE PLANES

(80) Thru the origin, O, Fig. 16, (a) and (b), are drawn three directrices as shown; one *horizontal,* a second *vertical,* and the third to the *right* or *left* at 45°, 30°, or

60° with the horizontal, preferably 45°. These three lines represent lines at *right angles* to each other, and may be compared to the *three adjacent edges* of a *cube.*

Taken two and two, these directrices include coordinate planes as follows: OA and OB, plane 1, or the plane of *true circles;* OB and OC, plane 2, a second vertical plane, and OA and OC, plane 3, a horizontal plane.

DIMENSIONING

(81) In oblique as well as in isometric projection, the problems of dimensioning are threefold; i. e., any object drawn may have faces parallel to each of the three coordinate planes in Fig. 17. In placing dimensions for constructions on these faces it is necessary, of course, to decide what directions constitute from *left* to *right* and from *bottom up.* The key in Fig. 18 may be used in a manner similar to that of the key given for isometric projection. Inspection of Figs. 19-23 may serve to clear up any doubtful points, both in dimensioning and in construction.

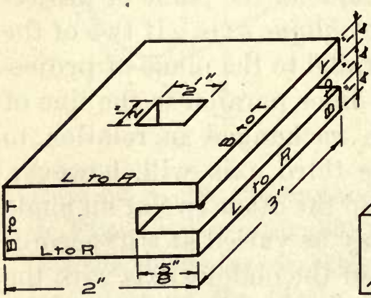


Fig. 17

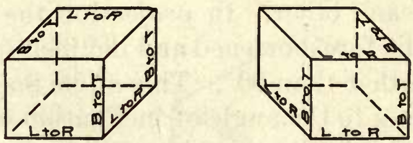
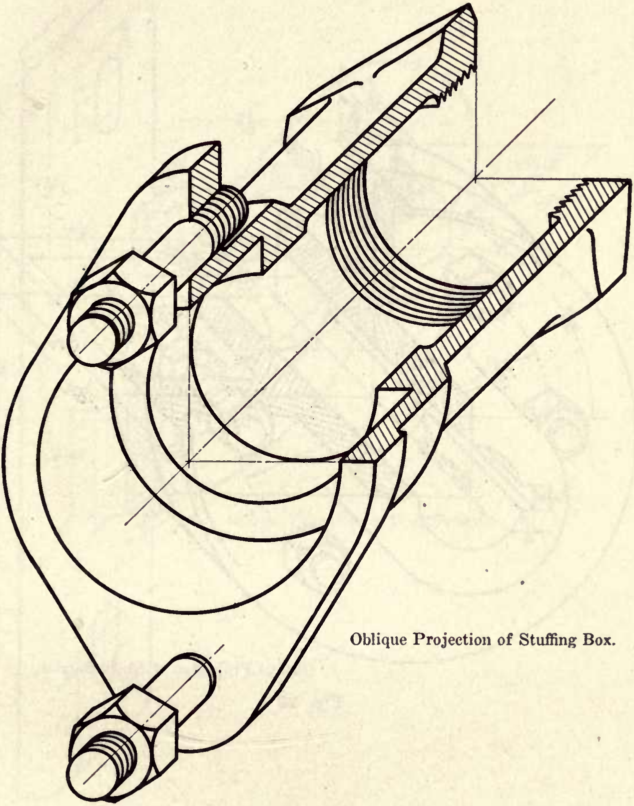


Fig. 18

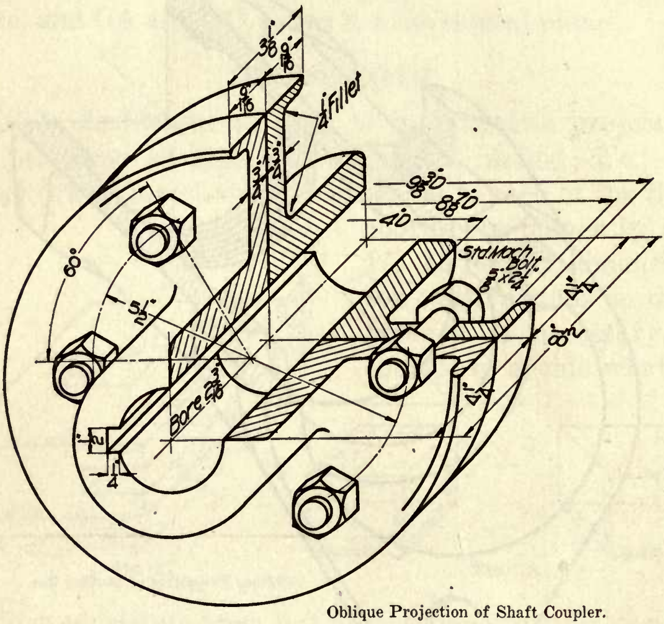
OBLIQUE SCALE

(82) If *equal distances* be measured from O along the axes OA, OB and OC, Fig. 24, the distance along



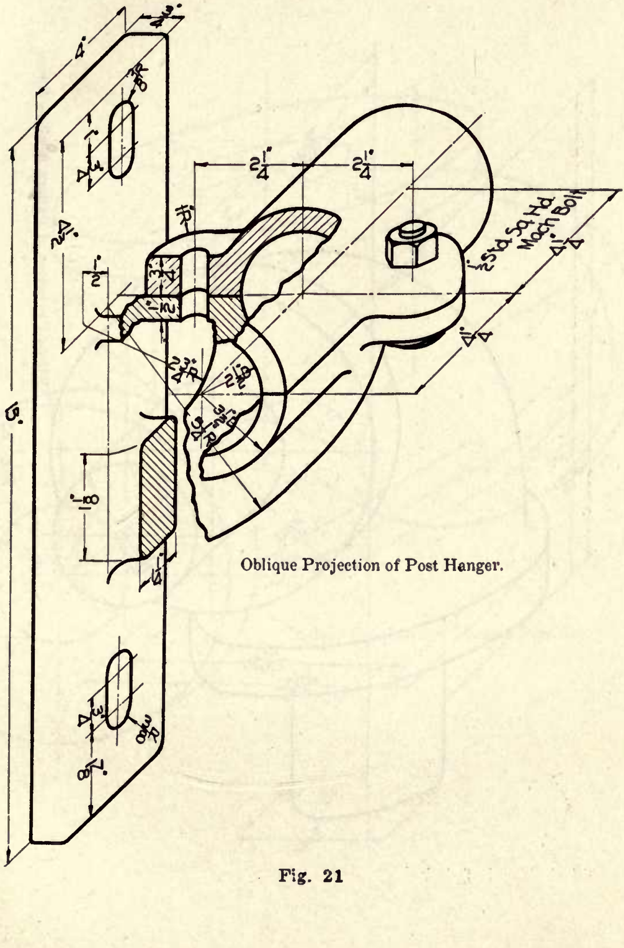
Oblique Projection of Stuffing Box.

Fig. 19



Oblique Projection of Shaft Coupler.

Fig. 20



Oblique Projection of Post Hanger.

Fig. 21

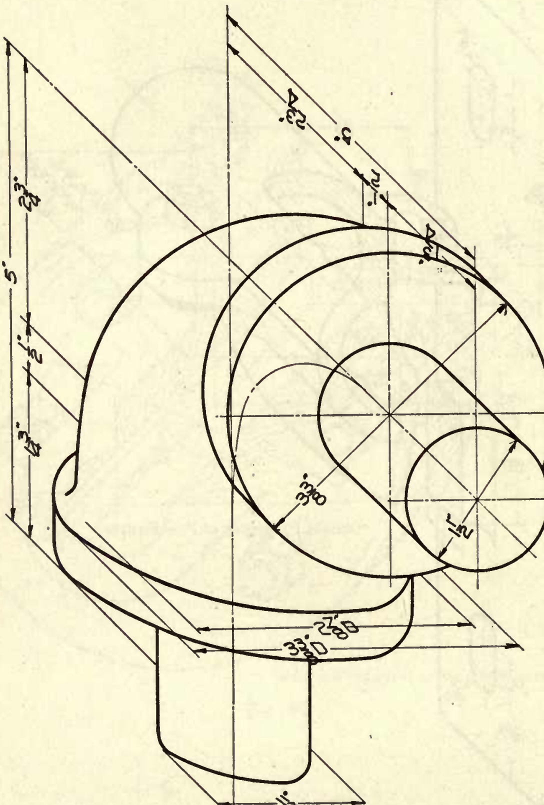
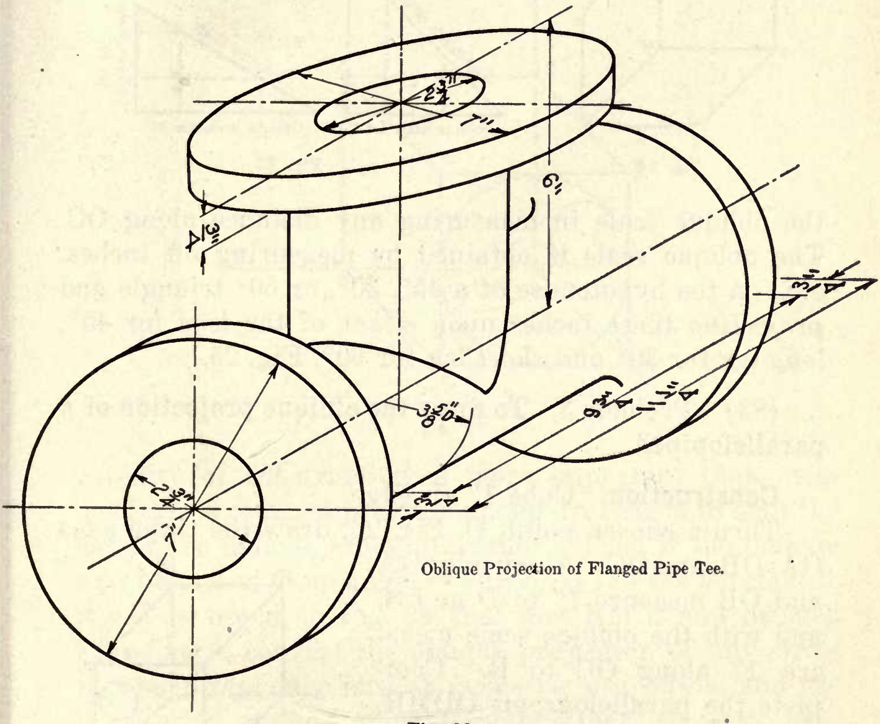


Fig. 22

Oblique Projection of Pattern for Pipe Elbow.



Oblique Projection of Flanged Pipe Tee.

Fig. 23

OC will appear to be *longer* than those along OA and OB; hence, for symmetry, it is necessary to make use of

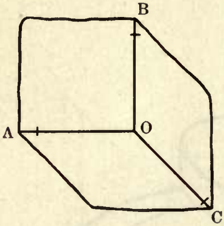


Fig. 24

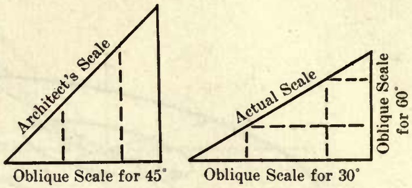


Fig. 25

the oblique scale in measuring any distance along OC. The oblique scale is obtained by measuring off inches, etc., on the hypotenuse of a 45°, 30°, or 60° triangle and *projecting* these inches upon *either* of the *legs* for 45°, *long* leg for 30° and *short* leg for 60°, Fig. 25.

(83) Problem 3. **To draw the oblique projection of a parallelopiped.**

Construction. Cube 1″ on edge.

Thru a chosen point, O, Fig. 26, draw the three axes OA, OB, and OC. Along axes OA and OB measure 1″ to D and S, and with the oblique scale measure 1″ along OC to R. Complete the parallelograms ODMR, OSLR, and DNSO; then the remaining faces may easily be added.

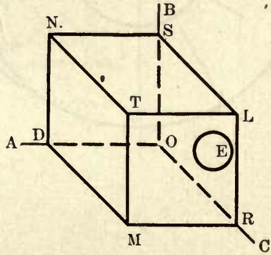


Fig. 26

CIRCLES

(84) Point E, in face TLRM, Fig. 27, is the center of a circle ¾″ diameter. Since this is the face of *true*

circles, the circle may be constructed with the compass. If it is desired to draw the projections of circles lying in faces TNSL or NTMD the *8-point* method explained in isometric projection may be used. In cases where

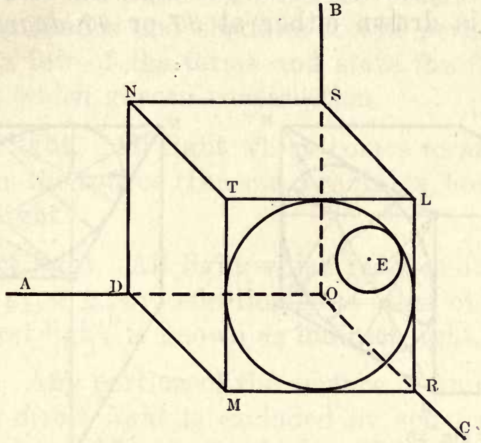


Fig. 27

rapidity of construction is more important than symmetry, it is common practice among draftsmen to omit the use of the oblique scale altogether. Then if the oblique axis be drawn at an angle of *30 degrees* to the *horizontal,* it will be noted, in Fig. 28, that face NM is now of such shape as to convert the oblique projection of any circle placed in that face into an *isometric projection,* and the *mechanical method* of constructing that isometric projection, shown in Fig. 12, can and should be used. If, on the other hand, the *oblique axis* be drawn at an angle of *60 degrees* to the *horizontal,* Fig. 29, the face NL is now of such shape as to convert the *oblique projection* of any circle placed in it into an *isometric projection* which can be constructed *mechanically* by the method of Fig. 12.

With some care it will usually be possible, in making the oblique projection of any object containing circles, so to place the object that the oblique projections of some of the circles are *true circles,* while the projections of the remainder become *isometric* when the *oblique axis* is drawn either at *30* or *60 degrees* to the *horizontal.*

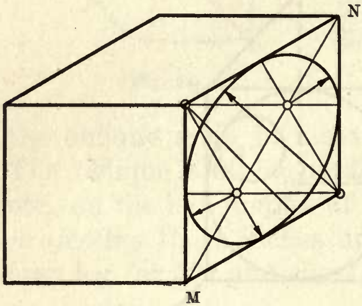


Fig. 28

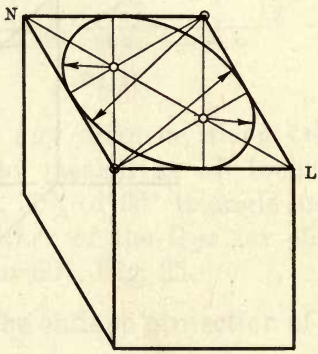


Fig. 29

IRREGULAR OBJECTS

(85) All that has been said on this subject under isometric projection applies as well in oblique projection. It is perhaps unnecessary to suggest that when making any oblique projection care should be taken so to place the object that most of the circles will appear as *true* circles.

SHADES AND SHADOWS IN ISOMETRIC AND OBLIQUE PROJECTION

(86) Shades and shadows, in isometric projection as in orthographic projection, are used merely for the

natural appearance which they give to a drawing. Hence, as in orthographic projection, the draftsman has considerable freedom in determining both the *direction* and the *length* of the shadows. Before proceeding with a problem in shades and shadows it will perhaps be well to define a few of the terms and state the fundamental principles which govern construction.

Direct light. All light which comes to any body directly from the source (the sun, arc lights, etc.) is known as **direct** light.

Indirect light. All light which reaches objects in an indirect way, e. g., by reflection from other objects which are in direct light, is known as **indirect** light.

Shade. Any portion of the surface of an object from which the *direct light* is excluded by some part of the *same* object is said to be **in shade.** This shaded surface may also be known as a **shade.**

Shadow. Any portion of the surface of an object from which the *direct light* is excluded by some part of *another* object is said to be **in shadow,** and for convenience may be called a **shadow.**

PRINCIPLES

1. All rays of light in these problems are regarded as *parallel;* hence, when the direction of the first ray has been assumed, all others must be considered parallel to it.

2. The shade or shadow of a given point on a given surface is the point in which a ray thru the given point pierces the given surface.

3. Any *ray* used to determine the *shade* or *shadow* of a given point may in reality be a ray of light; however,

in this discussion it will be known as a **shadow ray**; see Miller's *Descriptive Geometry,* Art. 124.

4. If a line AB is parallel to a plane, e. g., H, the shadow of AB on H is *parallel* and equal in length to AB.

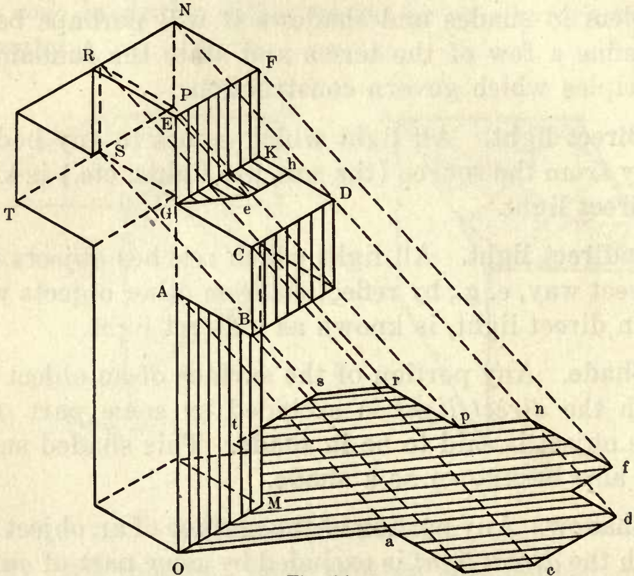


Fig. 30

5. If lines AB and CD are *parallel* the *shadows* of AB and CD on any plane must be *parallel,* i. e., the *shadows* of *parallel lines* are *parallel.*

6. If a line AB is oblique to H, AB and its shadow on H will meet at the point in which AB pierces H.

7. The *shadows* of *parallel lines* on *parallel planes* are *parallel.*

(87) Problem 4. **To find the isometric or oblique projection of the shade and shadow on H of a given object.**

Given. Isometric and oblique projections of Cross, Figs. 30 and 31.

Req'd. Isometric and oblique projections of shade and shadow on H.

Beginning with point O as an origin, a line may be drawn in any desired direction, e. g., O*a*, to represent the shadow of OA, and point *a* assumed in any desired posi-

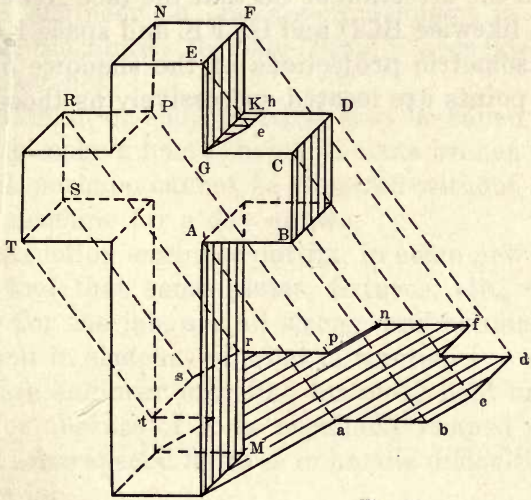


Fig. 31

tion as the shadow of point A. A*a* is the isometric projection of the shadow ray thru A, and all other shadow rays must be *parallel* to A*a*. Since AB is parallel to H, its shadow *ab* is parallel and equal in length to AB. BC is parallel to OA, hence its shadow *bc* is parallel to O*a*, and *c* is determined by shadow ray C*c*. CD is parallel to H, hence its shadow *cd* is parallel and equal in length to CD; *d* may likewise be located by the shadow ray D*d*. Since the plane GCDK is parallel to H, the shade of GE on this plane is parallel to O*a*, see Principle 7, and *e* is located by the shadow ray from E. EF is parallel to

GCDK, hence the shade line from *e* is parallel to EF; to find the shadow of F draw the shadow of MF parallel to Oa; the intersection of this shadow line with the ray thru F locates f. The shadow of EF is paralled to cd; *fn* is parallel and equal in length to FN. It is readily seen from the direction of O*a* that the face AOM must be in shade, likewise BCD and GEFK and space KG*eh*.

The isometric projections of the shadows of the remaining points are located successively as those already found.

CHAPTER 8

MACHINE SKETCHING

(88) **Definition.** A **machine sketch** may be roughly defined as a *freehand working drawing.*

To the engineer no one accomplishment is of more value than the ability to make rapidly accurate, legible machine sketches.

A draftsman or shop foreman may be called upon at any time to make a hasty sketch of some broken machine part which perhaps cannot be removed without shutting down the machine for a day or two.

A construction engineer putting in some new machinery may find that some plates, fixtures, etc., designed especially for the job, are all wrong, and he must immediately send in sketches of what is wanted.

A bridge engineer may find his work held up by the breaking or absence of some peculiarly shaped piece, or may need some special fixtures to handle difficulties peculiar to the job.

Likewise, it is understood that all machine forms are devised in the mechanic's brain and must be placed on paper in some approximate form before it is possible to make a mechanical working drawing.

In all of these and hundreds of other cases which are inevitable, the ability to sketch *rapidly* and *well* is indispensable, and the man who finds himself called upon to make a sketch and is not well grounded in its principles, will find himself seriously handicapped.

PAPER

(89) It will be seen that the nature of the situations

which require sketching will demand the use of scratch paper or a notebook. *Cross-section paper* is invaluable for this purpose, as it aids materially in the rapid and accurate sketching of the several views.

NATURE OF DRAWING

(90) As in a *mechanical working drawing,* a *machine sketch* consists of a number of views (*top* and *front; top, front,* and *left end,* etc.) of a machine or machine part. These views are true orthographic projections, hence projections of each other, as in working drawings. Never show more views than are necessary to explain clearly the construction; of course, *two* are a *minimum;* variations in this respect will be mentioned later.

PENCIL—SKETCH STROKE

(91) For sketching it will be better to use a comparatively *soft* pencil, H or 2H, as it is desirable to show marked distinction between the outlines of the *object* and *dimension* and *section* lines.

In drawing lines, whether short or long, the *sketch stroke* should be used. The **sketch stroke** is merely a *succession* of *short strokes* in the desired direction, and, as a result, the line will, of course, be somewhat ragged, consisting of a number of short overlapping lines. However, by this method it will be found possible to approximate a straight line much more closely than by a continuous stroke.

SIZE OF DRAWING

(92) The work being freehand and done usually under adverse conditions, sketches are not made to scale; *numerical dimensions* are depended upon en-

tirely for sizes. As an aid in approximating proportions of the different parts of a machine, the following scheme will be found useful: Suppose after careful inspection it is decided that only two views are necessary, and these *front* and *right end.* You have perhaps a 5 x 7 notebook at hand and must place these two views, with dimensions, on this size sheet. Estimate the ratio of the *length* of the object to its *width* and *height* and block out roughly on the sheet the proper proportional spaces, for the two views, making them as large as possible. Then measure off on a lead pencil with the thumb-nail a distance equal to the length you have given the space for the front view, and, holding the pencil horizontally and about 1′ from the eye, move off from the machine until the space from the end of the pencil to the thumb-nail just covers the length of the machine. Standing in this position and using the pencil in this manner, the several parts of the machine may be rapidly sketched in their proper sizes.

PROCEDURE

(93) In making a machine sketch, the greatest speed and accuracy will be attained by following some system. The following will be found valuable:

1. Decide on the *number* of *views necessary,* and decide which these should be.

2. Estimate ratio of length to width of machine and *block out* on sheet *proportional spaces* for above views.

3. Sketch in all *outlines* **(working on all views at the same time).** Do not attempt to finish one view entirely before working on the other; when a line is placed on one view, place its projection on the other view so that all views are finished at approximately the same time.

4. Sketch in *dimensions, auxiliary,* and *section lines.* The reason for placing on dimension lines while making up the views is, that each detail of the piece as it is drawn may suggest a necessary dimension that perhaps would be overlooked if left until later. A break should be left in each dimension line. No attempt need be made here to distinguish between outlines and other lines.

5. Go over the sketch carefully and increase the *weight* of *outlines* so that the construction shows easily.

6. Obtain from the machine with calipers and rule all dimensions already indicated on sketch. **Always** place on *overall* dimensions as a check.

7. Be *liberal* with notes.

SHORT CUTS

(94) To save time, the following short cuts are permissible:

1. In drawing objects of familiar shape, wheels, etc., the hub, two spokes, and a short portion of the rim is sufficient.

2. Where objects are symmetrical with respect to a center line, e. g., gate valves, etc., it is sufficient to show only one-half of object, limiting the portion drawn by the center line. The other half may be drawn in when time permits, if desired.

3. Where objects are symmetrical about two center lines at right angles to each other, it will be sufficient to show only one-fourth of the object.

4. Where any part cannot be shown well in detail, e. g., bolts, holes, fasteners, etc., explanatory notes may be substituted—e. g., 3/8″ *drill;* 3/4″ x 10 *pi. tap;* 3/4″ *Hex. Hd. Mach. Sc.;* etc.

CHAPTER 9

PERSPECTIVE

(95) Tho it is impossible to give here any complete explanation of the principles of perspective, it has been deemed advisable to attempt sufficient explanation to enable one to understand a few of the basic principles.

It is readily seen that no one view of a working drawing of any object can present to the eye the natural appearance possessed by a crayon or charcoal drawing. The reason is, that in making a working drawing the eye was imagined at an *infinite* distance from the object, an assumption so unnatural as to give rise immediately to results of an unnatural appearance.

PERSPECTIVE DRAWING

(96) **Definition.** A **perspective drawing** of an object is *such a representation of that object on a given plane or sheet of paper as will present the same appearance as the object itself when the eye is in a certain position with respect to the object.*

The plane on which the perspective drawing is made is called the **picture plane,** and, for reasons which need not be given here, is usually taken *vertically.*

PRINCIPLES OF CONSTRUCTION

(97) The principle on which perspective construction is based is as follows: The *vertical picture plane* is placed *between* the *eye* and the *object* (that the drawing may be *smaller* than the object), and **lines of sight** or **visual rays** drawn from the eye to the various points

of the object. The *points* in which these lines *pierce* the *picture plane* are respectively the *perspectives* of the corresponding points of the object. If lines be drawn connecting these *piercing points* in their proper order, a perspective drawing of the whole object is obtained. Fig. 1.

PICTURE PLANE AND POSITION OF OBJECT

(98) Since perspective drawings are made mostly from working drawings, the *vertical plane* of *ortho-*

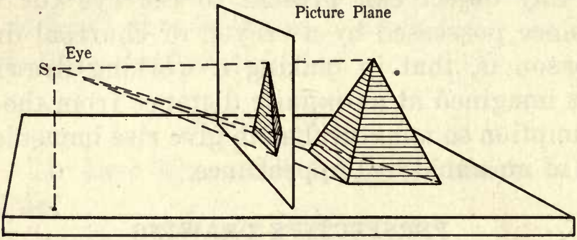


Fig. 1

graphic projection is used as the *picture plane* and the object placed in the *third angle.*

POSITION OF POINT OF SIGHT

(99) The *point* of *sight* is, of course, in *front* of the vertical plane, and may be in either the *first* or *fourth* angles, according to the nature of the view desired; i. e., if it is desired to make a drawing showing the appearance of the object when directly in *front* of it, the point of sight would be in the *fourth* angle.

PRINCIPAL POINT IN PERSPECTIVE

(100) The projection of the *point of sight* on the vertical plane is called the **principal point** in perspective, and is of prime importance in construction. Inasmuch

as the vertical projections of points are designated thus, *a′*, *b′*, *c′*, etc., the vertical projection of the *point* of *sight*, S, will be indicated by *s′*.

PRINCIPAL POINT THE VANISHING POINT OF LINES PERPENDICULAR TO THE PICTURE PLANE

(101) It is a familiar fact that as one stands near a long straight section of railroad track the two lines of rails appear to meet off in the distance. So it is with any set of parallel lines; if the eye follows them for a distance—and, when speaking geometrically, we give this distance a value of *infinity*—they all appear to meet in one point. This point we call their **vanishing point.** When our line of sight follows out these parallel lines to *infinity*, where they appear to meet, for all practical purposes the *line* of *sight* is *parallel* to the given set of lines. Reference to Fig. 2 may serve to make this explanation clearer. Point S represents the position of the *eye*. A cube BD rests on a horizontal

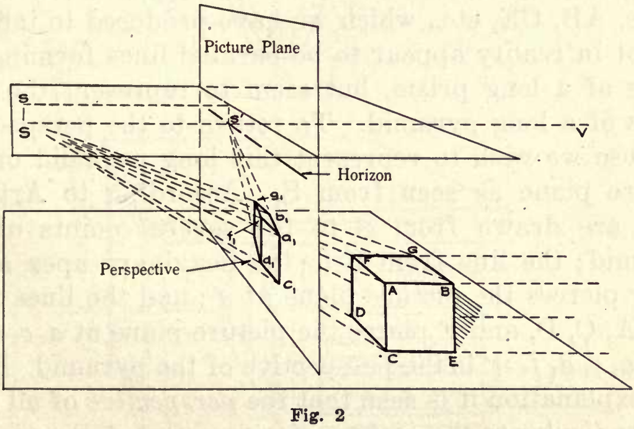
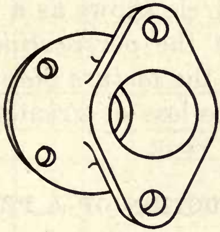


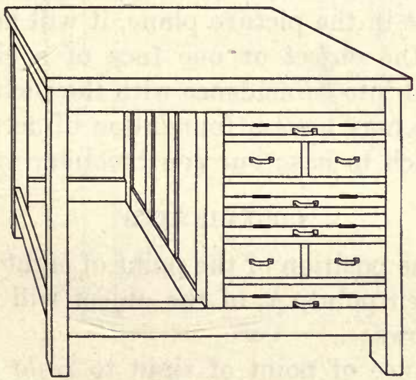
Fig. 2

plane on the other side of the picture plane. The four parallel edges, AB, CE, etc., of the cube are produced as indicated by dotted lines to the right; if they are produced an infinite distance they will appear to meet, and the line of sight from S to the apparent meeting or vanishing point is the line thru S and V. Then, as explained above, if SV meets AB, CE, etc., at infinity, it is *parallel* to them. But AB, CE, etc., are *perpendicular* to the *picture plane;* therefore the line thru S and V out to this vanishing point is also *perpendicular* to the *picture plane* and must pass thru s', the projection of S on the picture plane. As viewed from point S, the four edges, AB, CE, etc., which we have produced to infinity, do not in reality appear to be parallel lines forming the edges of a long prism, but seem to represent the four edges of a long pyramid. To return to the perspective, suppose we wish to represent this long pyramid on the picture plane as seen from S. According to Art. 97, lines are drawn from S to the several points of the pyramid; the line from S to the imaginary apex at infinity pierces the picture plane at s'; and the lines from S to A, C, D, and F pierce the picture plane at $a_1\ c_1\ d_1\ f_1$; then $a_1\ c_1\ d_1\ f_1\text{-}s'$ is the perspective of the pyramid. From this explanation it is seen that the *perspective* of all *lines perpendicular* to the *picture plane* meet at s', the vertical projection of the point of sight. For this reason s' is called the **vanishing point** of perpendiculars. The fact that perpendiculars do converge at s' affords an easy method of constructing the perspective of any object when placed in a certain position. Lines from S to the other points of the cube are seen to pierce the picture plane in points on the perspectives of these perpendiculars, giving the figure $b_1\ a_1\ c_1\ d_1\ f_1\ g_1$. This figure represents the cube as seen from S. Face ABEC is not visible from S.

THE HORIZON IN PERSPECTIVE

(102) Any line which is perpendicular to a vertical plane is horizontal. In Fig. 2 the lines AB, CE, etc., are horizontal lines and, when produced an infinite distance,





appear to meet in a point on what we commonly call the **horizon.** Then the *line* of *sight* from S to this meeting point becomes a *horizontal line,* and the *perspective* of the *horizon* will be the *horizontal line* drawn thru the point s'. The horizontal line lying in the picture plane and passing thru the vertical projections of the point of sight, s', is also called the **horizon.**

SPECIAL POSITION OF THE OBJECT

(103) If the cube in Fig. 2 be moved until face ACDF coincides with the picture plane, then this face becomes its own perspective and each line on this face is shown in its true value; i. e., a circle shows as a true circle, etc. From this it follows that the *perspective* of any *circle* whose *plane* is *parallel* to the *picture plane* will be a *true circle;* its diameter will be less or greater than the true diameter, however.

MECHANICAL CONSTRUCTION OF A PERSPECTIVE

(104) Inasmuch as all lines in perspective are shorter than the lines which they represent, except in the case of lines which lie in the picture plane, it will be best to put one face of the object or one face of a circumscribed parallelopiped into coincidence with the picture plane, in order that we may have a foundation of actual measurements on which to base our construction.

COORDINATES

(105) The position of the point of sight with respect to some chosen point, A, of the object will hereafter be given as follows:

$x =$ distance of point of sight to *right* or *left* of A as x is $+$ or $-$.

$y =$ distance of point of sight *above* or *below* A as y is $+$ or $-$.

$z =$ distance of point of sight *before* the point A; e. g., $x = 3''$, $y = -4''$, $z = 6''$ *locates* S 3″ to the *right* and 4″ *below* A and 6″ *before* the picture plane.

(106) Problem 5. **To draw the perspective of a cube $1\frac{1}{4}''$ on edge, one face of the cube coinciding with the picture plane;** $x=-2''$, $y=1''$, $z=4''$. A is taken at corner A.

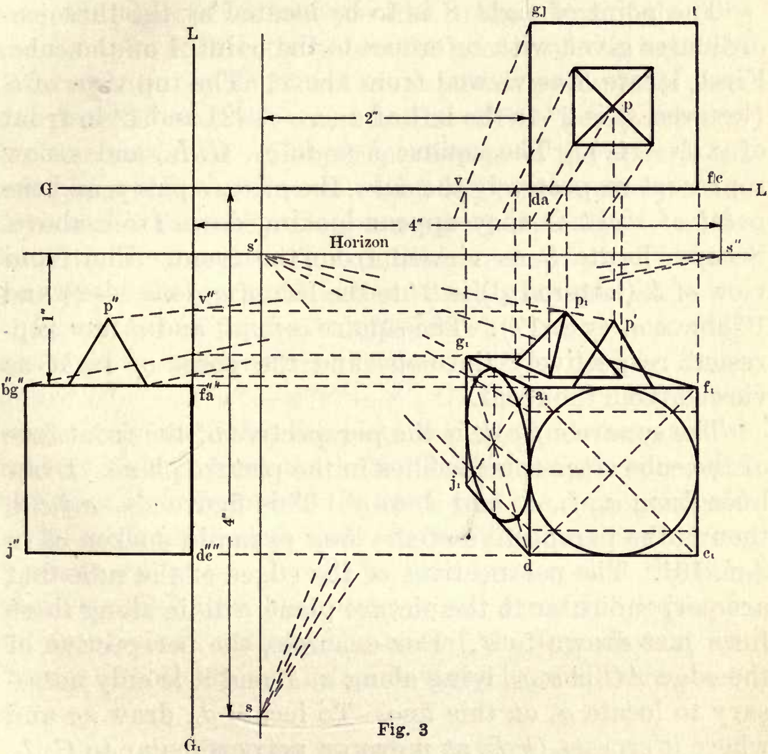


Fig. 3

Construction. See Fig. 3.

Draw well toward the top of the sheet a horizontal line *G. L.*, the intersection of the horizontal and vertical planes. Since the picture plane coincides with the vertical plane this line, G. L., represents the picture plane as seen from the top. Construct in a convenient position the top view *b-fc-da-gj* of the cube, the line *da-fc*, which represents the front face of the cube, coinciding with *G. L.* At any desired distance directly below the top view, draw the square $a_1f_1c_1\, d_1$ which is the front view of the cube.

The point of sight *S* is to be located by the three coordinates given with reference to the point *A* on the cube. First, locate *S* as viewed from above. The top view of *S* (lettered *s*) is 2″ to the left of *a* (x = —2) and 4″ in front of *a* (z = 4″). The square *b-fc-da-gj, G. L.*, and *s* now represent respectively the *cube*, the *picture plane*, and the *point of sight* as they appear looking down from above. Second, locate *S* as viewed from the front. The front view of *S* (lettered *s′*) is 2″ to the left of a_1 (x = —2) and 1″ above a_1 (y = 1″). The square $a_1f_1c_1d_1$ and *s′* now represent respectively the *cube* and the *point of sight* as viewed from the front.

The square $a_1f_1c_1d_1$ is the perspective of the front face of the cube since this face lies in the picture plane. Draw lines from a_1, f_1, c_1, and d_1 to *s′*. This figure $s' — a_1f_1c_1d_1$ then is the perspective of the long pyramid spoken of in Art. 101. The perspectives of the edges of the cube that are perpendicular to the picture plane will lie along these lines just drawn to *s′*. For example, the perspective of the edge *AG* is a_1g_1, lying along $a_1\, s'$ and it is only necessary to locate g_1 on this line. To locate g_1, draw *sg* and where it crosses *G. L.* at *v* drop a perpendicular to *G. L.* until it intersects $a_1\, s'$. Since *sj* coincides with *sg*, j_1 will lie directly below g_1 on d_1s' and the perspective of the left side of the cube is completed as $a_1g_1j_1d_1$. A horizontal line from g_1 produced until it interesects f_1s', completes the perspective of the cube. It is easily seen that *sg* is the top view of a line of sight from S *to* G and was drawn to ascertain the distance vd to the left of the edge FD of the cube at which the line of sight pierces the picture plane.

It is desired to place a small pyramid on top of the cube, the edges of its base parallel to the edges of the cube and its apex P directly above the center of the top face. Construct the top and front views of the pyramid in place and proceed with the construction of the perspective of the base as shown. The perspective p_1 of the apex is the point in which the line of sight sp pierces the picture plane and is found by dropping a perpendicular from the point where sp crosses $G. L.$ until it meets $s' p'$. The perspective of the pyramid is then readily completed.

In certain instances, a left side view will be an additional aid in constructing the perspective. In Fig. 3, the square $b''g''—f''a''—d''c''—j''$, $G_1 L_1$ and s'' represent respectively the cube, the picture plane and the point of sight as viewed from the left. The line $s''p''$ represents the line of sight from s to the apex p of the small pyramid as viewed from the left and a horizontal line drawn from v'' meets $s'p'$ at p_1. It will be readily seen that the perspective could have been determined from the left side and front views without the use of the top view at all. The use of both top and left side views is usually unnecessary.

CIRCLES IN PERSPECTIVE

(107) The **8 point method** may be used in constructing circles in perspective. This is illustrated on the cube in Fig. 3. The diagonals can easily be drawn and the points of tangency of the perspective with the upper and lower lines $f_1\ g_1$ and $d_1\ j_1$ determined by drawing a vertical line thru the intersection of the diagonals.

IRREGULARLY SHAPED OBJECTS

(108) Any irregularly shaped object may be easily drawn in perspective by first enclosing the object in a parallelopiped and referring the several constructions of the object to lines of the parallelopiped.

POSITION OF POINT OF SIGHT

(109) Considerable care and judgment must be used in placing the point of sight, for it is easily understood that a house viewed from a point only two feet in front of it would look absurd; however, its perspective can be constructed as easily under such circumstances as any other. It is well to estimate approximately from what particular position we would likely view that object to obtain the best view, taking into account the size of the object in this estimate. The point of sight may then be placed accordingly. For large objects a safe rule is to place the point of sight in front of the object a distance equal to twice the greatest dimension. For smaller objects we may increase this to 4 or 5 times the greatest dimension.

APPENDIX

PHOTOGRAPHIC REPRODUCTIONS

Blueprinting. Blueprinting is in short a process of simple photographic reproduction on sensitized paper, of drawings which have been made on some translucent material; this material may be *tracing cloth, tracing paper,* or ordinary paper *oiled* after the drawing has been finished. In common practice the process is somewhat rough as one would infer from a glance at the average print; however, with care it can be carried nearly to the same limits of refinement as other photographic printing.

BLUEPRINT PAPERS

Occasions may arise when it is necessary to sensitize paper for blueprinting; however, unless absolutely necessary no draftsman should ever bother to coat his own paper, for it is a tedious and most unsatisfactory process. The machine-coated papers sold by any of the instrument companies in 10 or 50-yard rolls of any width and of any desired thickness or quality of paper is cheap, keeps well for months in a tin tube, and always gives better results than paper coated by the amateur. For prints which must stand extra hard use, either mounted paper (cloth-backed paper) or blueprint cloth (a smooth, hard-surfaced, sensitized cloth) should be used; the latter, however, seldom gives the sharp detail obtainable on paper. Below is tabulated information that will be of value in ordering papers or cloth.

Blue Print Paper and Cloth

PAPER		CLOTH	
WEIGHT	USE	WEIGHT	USE
Extra thin	For sending thru mail. Not satisfactory for shop use, too thin.	Extra thin	Large prints which are to receive extra hard wear.
Thin	For large prints that would be too bulky on heavier paper.	Medium	Small maps, moderate sized prints that receive extra wear.
Medium thick	Best for all ordinary use, shop, construction work, etc.		
Thick	For durable small prints; maps, land plots, etc.		

Printing Speed in Bright Sunlight

Regular	Rapid	Extra Rapid	Elec. Rapid
4 min.	2 min.	40 sec.	25 sec.

In ordering paper be sure to state the printing speed desired; e. g., 1 roll; 50 yds. x 36 in., Extra Thin, Electric Rapid, Blue Print Paper.

TO SENSITIZE PAPER

Paper. Only "unsized" and well-washed papers are suitable for blueprinting. The *size* used on many papers to give it a glossy and easy writing surface discolors the blueprint solution immediately. Likewise paper from which the sulphur, used in its manufacture, has not been well washed will discolor. Practically any unsized "bond" or "parchment" paper will be found satisfactory for printing.

Solution. The formula in most common use for the sensitizing solution is: (1) Red prussiate of potash, 1 oz.; water (distilled), 4 oz.; (2) double citrate of iron and ammonia, 1 oz.; water (distilled), 4 oz. As long as these solutions are kept separate sunlight has no effect upon them. However, the second solution should be kept in a well stoppered bottle of dark colored glass.

To sensitize the paper, mix *equal* volumes of the above solutions and apply either with a camel's hair brush, brushing first horizontally, then vertically, to insure even coating, or float the paper for a few seconds in a shallow granite pan partially filled with the solution, and hang by one corner to dry. This sensitizing must of course be done in a dark room. If the solution of citrate of iron is kept too long it may mold and spoil; hence, as the crystals dissolve quite readily it may be best to make this solution only when it is to be used and then only what is needed. The bottle in which the citrate is kept should be glass stoppered to prevent moisture from melting down the crystals. The prussiate does not dissolve so readily and as it does not spoil it can be kept in solution in any quantity.

VANDYKE SOLAR PAPER

Vandyke Solar Paper, sometimes called "Brown Print" paper, is a brown paper used in making negatives for *positive printing.* A print is made on Vandyke paper from a tracing, the *inked side* of the tracing being in this case turned **to** the paper, so that a reversed print is obtained. The lines of the drawing show up *white* on a deep *brown* background. This paper is then rubbed with oil to make it more transparent and positive blueprints are made from it, the *brown side* of the negative being turned **toward** the blueprint paper. In this final print the lines of the drawing show up *blue* on a *white* background instead of the reverse in direct printing from the tracing.

WASHING AND FIXING VANDYKES

Vandyke paper has been sufficiently exposed when the surface not covered by the black lines of the tracing has turned a *light bronze* color. After washing for a few minutes, **face down** in the tank, the print should be **fixed** with a solution of 1 oz. of hyposulphite of soda to 1 qt. of water. The print may be laid on a board and the solution applied with a brush or better still the print may be floated **face down**, in a granite pan partially filled with the hypo solution; one brushing or a few seconds floating is sufficient. The print should then be washed again **face down**, to remove the surplus hypo.

TO TRANSPARENTIZE VANDYKES

It is possible to obtain positive prints from unoiled Vandykes; however, if the negative has been rendered more transparent by oiling the printing time will be materially reduced. Any clear oil or white grease will answer for this purpose, *white tube vaseline* being perhaps the most convenient. The following formula gives a transparentizing oil that works well: 4 oz. banana oil, 10c tube white vaseline. (Mix the two by heating slightly and keep in a stoppered bottle.) The banana oil furnishes a quick "drier" and the vaseline a permanent oil. If there is much transparentizing to be done it is well to keep a ball of waste, soaked in the above solution, in a covered tin can. Never apply more grease than will dry in a few minutes and be sure to oil the side of the paper which is to be turned **toward** the light. Unless necessary **never** use **paraffin** for transparentizing; it renders the paper very brittle and any wrinkles in a paraffined negative show plainly on the print.

POSITIVES ON OLD VANDYKE PAPER

In making positive prints on old Vandyke paper some little care must be exercised. When printed and washed the unexposed or white parts turn decidedly yellow; this can be prevented if the print is merely dipped in the water to wet the surface and start the printing out and immediately floated on the fixer; the fixer will print out the lines and prevent the background from turning yellow. These precautions are not necessary in making negatives on old paper, for tho unexposed parts may turn yellow the negative will print well when oiled.

BLUEPRINTING FROM TYPEWRITTEN SHEETS

To obtain clear sharp prints from typewritten sheets a moderately thin hard surfaced paper and new black typewriter ribbon should be used. If there is much work to be done it will be well to obtain an extra heavily inked ribbon. In typewriting place *under* the the paper a sheet of black carbon paper with carbon face **toward** the paper; thus an impression is obtained on both sides of the paper. Use each sheet of carbon paper only **once** for this purpose.

In oiling, one may not rub these sheets, as the carbon will smear. Instead, lay over the typewritten sheet a square of oily cotton flannel, then a sheet of heavy paper and roll with a small picture mounting roll. Or better, if time permits, lay pieces of oily cotton cloth between the sheets and weight down with a heavy book for several hours. Arrange sheets and cloth as follows: Paper, cloth, two sheets of paper, cloth, two sheets of paper, cloth, etc. In printing from these sheets, over expose the paper slightly and wash in water to which hydrogen peroxide has been added in the proportion of ½ teaspoonful to 2 gallons water; the hydrogen peroxide will bring out the over exposed parts and deepen the blue. The above solution can be used to advantage in washing any blueprints; a sharper contrast between the white lines and blue background can be obtained.

PRINTING FROM OLD BLUEPRINTS

Occasionally reproductions of drawings are wanted when the tracings are not available. By use of the "Direct Copier" of the Frederick Post Co., Chicago, an old blueprint may be rendered sufficiently dense to act as a good negative. This "Direct Copier" consists of two concentrating solutions to be applied to the old blueprint to deepen the blue; the transparentizing oil must then be used to clear up the white lines. If the "Direct Copier" is not available and there is not sufficient time for a tracing a fairly good positive may be made from a blueprint by merely transparentizing it.

PRINTING FROM HEAVY CARDBOARD

If it is desired to make a blueprint of a drawing mounted or printed on heavy cardboard or of a drawing on mounted paper, the face of the drawing should be soaked with alcohol and immediately clamped in the printing-frame. The alcohol will not evaporate while closed in the frame nor will it dissolve the blueprint solution if it should soak thru the cardboard. The length of time required for printing will have to be learned from experiment.

PRINTING FROM COORDINATE PAPER

Coordinate paper printed in **red** gives better blueprints than the paper printed in blue or green. Always transparentize the coordinate paper before printing; it will save time in printing and give better results.

Positive blueprinting of typewritten sheets. Excellent negatives for positive printing of typewritten sheets may be made from *new black carbon paper* as follows: Remove the ribbon from the typewriter and place the carbon paper in the machine, **face up,** with a sheet of thin hard surfaced paper over it. A reversed impression will of course be obtained on the back of this sheet of paper and the better the quality of paper the more clear cut will be the letters on the carbon sheet. The reason for placing the carbon with face **to** the cover sheet is to obtain such an impression as to make it possible to place the carbon side of the paper **toward** the *glass* of the printing frame instead of toward the *blueprint paper.*

Handle the carbon paper very carefully; a finger mark or smudge may easily ruin the negative.

The time for printing will have to be determined by experiment; it should be somewhat longer than for printing from tracings.

LINE ENGRAVING ON ZINC

Process. Line engraving on zinc is essentially an etching process and the procedure is as follows: A glass plate is coated with a sensitive solution and a negative made thereon, by the use of a camera, from the drawing submitted. After development the film negative is removed from the glass plate and transferred to another glass plate in a reverse position, thereby converting it into a positive film. A second negative is now obtained upon the sensitized surface of a polished zinc plate. A compound composed largely of printer's ink and grease is applied to the surface of this negative. This coating adheres to the portions corresponding to the lines of the drawing and when the plate of zinc is immersed in acid the surface is eaten away except where protected by the ink and grease compound. The result is a duplicate on the zinc plate of the original drawing.

Drawings. In order that one may secure the best possible line engraving on zinc especial care should be taken with the drawing. The paper used should be either white or bluish white; ordinary drawing paper, tracing cloth, or transparent vellum may be used. Very black water proof drawing ink should be used in making the lines, and care should be exercised that in erasing, the black lines are not dulled. If any parts of the lines are faded from erasing, they are not photographed sharply and the resulting lines may be somewhat ragged. So far the best ink that the writer has found for this purpose is the United States Blue Print Paper Company's Drawing Ink.

Reduction. In making a drawing for etching, it is best to make it of such a size that when reduced to one-half or one-third of its dimensions, it will be of the desired size for use; that is, if a diagram is finally to be 4 x 6 inches, the drawing had better be made about 8x12 inches. It should be remembered, however, that very fine lines do not reduce in the same proportion as heavy lines. To prevent very fine lines from disappearing entirely, the engraver will have to use methods which perhaps will increase them, and quite likely this increase will not be uniform, so that in making up a drawing care should be taken to make the lines about twice the desired final weight. For purposes of illustration hidden lines should be omitted and dimension lines should be made of secondary importance. Likewise, shading will be found useful in adding to the appearance of a drawing. For best appearance it is better to use printed letters than free-hand. This may be done by having all material which is to go on the drawing set up in type in a size about twice that finally desired, printing it on gummed paper, and pasting this material on the original drawing. Any lines which may be placed on the original drawing, and which are later found unnecessary or incorrect, may be simply marked over by the draftsman, with the understanding that the engraver is to paint them out; the only rigid requirements are that all lines be sharp, a dense black, and that the paper used be white.

WAX ENGRAVING PROCESS

Wherever it is impossible to submit a high grade line drawing from which to make the zinc line engraving, an accurate pencil or ink drawing or blue print may be submitted to any of the companies handling wax engraving work. This drawing or print is photographed on the sensitized wax surface of a copper plate. The photographed outlines are then scratched through the wax to the copper plate with appropriate tools. All necessary lettering is set in type and pressed into the softened wax. This wax engraving is then electrotyped, backed with type metal and mounted on a wooden block. Very clean cut legible lines result from this process, and it seems to be used very largely in making cuts of diagrams, curves, text book illustrations, etc.

A slight modification of this process is to make the drawing directly on the waxed covering of a copper plate, omitting the photographing process. The lines of the drawing are then scratched through to the copper plate and the procedure is as before. This scheme of engraving is very expensive, and perhaps will not be found profitable except as noted before in making cuts of charts, diagrams, curves, etc., on which a high degree of accuracy is desired.

HALF TONES

The half tone is the cut usually used in reproductions of photographs, wash or charcoal drawings, etc. It is perhaps unnecessary to explain in detail the process. It will be better to give some suggestions on the difficulties that may be encountered.

Drawings. It should be remembered always that when a half tone is to be made from a photograph, wash drawing, or drawing of any other description, that absolutely everything that can be seen by the eye on the original drawing or photograph, will likewise be seen and reproduced by the eye of the camera. It requires extremely careful work to paint out by the use of an air brush any lines which have been put in by mistake, and such work should be left to the engraver. It is possible to secure copies of high grade half tones which one may find in magazines, etc., by very carefully cutting out such half tones, trimming them very neatly, and pasting them on a background of white paper. Extreme care must likewise be exercised in pasting down such cuts that the background is not smudged by glue which may run from under the drawing, or by soiled fingers. The camera will surely see everything that can be seen by the eye.

Photographs. The type of photograph which seems to work best in the half tone process is that which is made on a glazed paper. If any great amount of work is to be made from photographs it will perhaps be better to consult with some good engraver for his advice on the kind of prints that he desires.

ABBREVIATIONS

METALS

Aluminum	Almn.
Babbitt	Bb.
Brass	B.
Bronze	Bz.
Carbon	Cbn.
Cast brass	C. B.
Cast copper	C. Cop.
Cast Iron	C. I.
Cast steel	C. S.
Cold rolled steel	C. R. S.
Copper	Cop.
Lead	Lead
Malleable iron	M. I.
Open hearth steel	O. H. S.
Phosphor bronze	Ph. Bz.
Steel	Steel.
Steel casting	S. C.
Wrought iron	W. I.
Zinc	Zn.
Tool steel	T. S.
Forged tool steel	F. T. S.
High speed steel	H. S. S.

GAGES

Brown & Sharpe, or American Standard Wire Gage	B. & S.
Birmingham, or Stubs Iron Wire Gage	B. W. G.
National, or Roebling's, or Washburn & Moen's	N. W. G.
Music Wire Gage	M. W. G.
United States Gage	U. S. G
Twist Drill & Steel Wire Gage	T. D. G.
Stubs' Steel Wire Gage	S. W. G.

FASTENERS

Button head bolt	Btn. Hd. B.
Cap screw	Cap Sc.
Double chamfered hexagon nut	Dbl. Chmfd. Hex. Nut.
Eye bolt	Eye B.
Fillister head brass machine screw	Fil. Hd. B. M. Sc.
Fillister head iron machine screw	Fil. Hd. I. M. Sc.

Flat head wood screw	Flat Hd. Wd. Sc.
Flat head stove bolt	Flat Hd. Stove B.
Headless set screw	Hdlss. Set Sc.
Hexagon nut	Hex. Nut.
Lag screw	Lag Sc.
Machine bolt	Mach. B.
Machine screw nut	M. Sc. Nut.
Milled body tap bolt	M. B. Tap B.
Set screw	Set Sc.
Square nut	Sq. Nut.
Stud bolt	Stud B.
T-head bolt	T-Hd. B.

WEIGHTS AND MEASURES, ETC.

Center	Cr.
Center line	C. L.
Circumference	Circum.
Diameter	dia. or D.
Foot, feet	Ft. or ′, e.g.4′
Horsepower	H.P.
Inch, inches	In. or ″. e.g.4″

MISCELLANEOUS

Building	Bldg.
Case harden	C.H.
Company	Co.
Counterbore	Cbr.
Countersink	Csk.
Cylinder	Cyl.
Drawing	Dwg.
General	Gnl.
Hexagon	Hex.
Machine	Mach.
Manufacturing	Mfg.
Maximum	Max.
Minimum	Min.
Specification	Spec.
Square	Sq.
Standard	Std.
Threads	Thds.
Weight	Wgt.
Finish	*f.*

REFERENCE TABLES

KEY FOR THE FOLLOWING TABLES OF BOLTS, NUTS, ETC.

A=Outside Diameter of Threads and Thickness of Nut.

B=Threads per Inch.

C=Tap Drill.

D=Across Flats.

E=Across Corners, Hex.

F=Across Corners, Sq.

G=Thickness of Collar.

H=Thickness of Head.

I=Across Flats.

J=Thickness Head and Nut.

K=Diameter Collar.

S=Width of Slot.—Decimals.

X=Angle of Head.

Hexagonal-Head Cap-Screw

A	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8
B	20	18	16	14	13	12	11	10	9
D	7/16	1/2	9/16	5/8	3/4	13/16	7/8	1	1- 1/8
E	1/2	37/64	41/64	23/32	55/64	15/16	1–1/64	1–5/32	1–19/64

Square-Head Cap-Screw

A	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8
B	20	18	16	14	13	12	11	10	9
D	3/8	7/16	1/2	9/16	3/8	11/16	3/4	7/8	1- 1/8
F	17/32	39/64	45/64	51/64	7/8	31/32	1- 1/16	1–15/64	1–19/32

Iron Set-Screw

A	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8
B	20	18	16	14	13	12	11	10	9
D	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8

U. S. Standard Bolts and Nuts

			Rough				Finished	
A	B	C	D	E	F	H	I	J
1/4	20	10	1/2	37/64	7/10	1/4	7/16	3/16
5/16	18	1/4	19/32	11/16	10/12	19/64	17/32	1/4
3/8	16	19/64	11/16	51/64	63/64	11/32	5/8	5/16
7/16	14	23/64	25/32	9/10	1-7/64	25/64	23/32	3/8
1/2	13	13/32	7/8	1	1-15/64	7/16	13/16	7/16
9/16	12	15/32	31/32	1-1/8	1-23/64	31/64	29/32	1/2
5/8	11	33/64	1-1/16	1-7/32	1-1/2	17/32	1	9/16
3/4	10	5/8	1-1/4	1-7/16	1-49/64	5/8	1-3/16	11/16
7/8	9	47/64	1-7/16	1-21/32	2-1/32	23/32	1-3/8	13/16
1	8	27/32	1-5/8	1-7/8	2-19/64	13/16	1-9/16	15/16
1-1/8	7	61/64	1-13/16	2-3/32	2-9/16	29/32	1-3/4	1-1/16
1-1/4	7	1-5/64	2	2-5/16	2-53/64	1	1-15/16	1-3/16
1-3/8	6	1-11/64	2-3/16	2-17/32	3-3/32	1-3/32	2-1/8	1-5/16
1-1/2	6	1-19/64	2-3/8	2-3/4	3-23/64	1-3/16	2-5/16	1-7/16
1-5/8	5-1/2	1-25/64	2-9/16	2-31/32	3-5/8	1-9/32	2-1/2	1-9/16
1-3/4	5	1-1/2	2-3/4	3-3/16	3-57/64	1-3/8	2-11/16	1-11/16
1-7/8	5	1-5/8	2-15/16	3-13/32	4-5/32	1-15/32	2-7/8	1-13/16
2	4-1/2	1-23/32	3-1/8	3-19/32	4-27/64	1-9/16	3-1/16	1-15/16
2-1/4	4-1/2	1-31/32	3-1/2	4-1/32	4-61/64	1-3/4	3-7/16	2-3/16
2-1/2	4	2-3/16	3-7/8	4-15/32	5-31/64	1-15/16	3-13/16	2-7/16
2-3/4	4	2-7/16	4-1/4	4-29/32	6	2-1/8	4-3/16	2-11/16
3	3-1/2	2-41/64	4-5/8	5-11/32	6-17/32	2-5/16	4-9/16	2-15/16
3-1/4	3-1/2	2-57/64	5	5-25/32	7-1/16	2-1/2	4-15/16	3-3/16
3-1/2	3-1/4	3-1/8	5-3/8	6-13/64	7-39/64	2-11/16	5-5/16	3-7/16
3-3/4	3	3-21/64	5-3/4	6-5/8	8-1/8	2-7/8	5-11/16	3-11/16
4	3	3-37/64	6-1/8	7-1/16	8-41/64	3-1/16	6-1/16	3-15/16
4-1/4	2-7/8	3-13/16	6-1/2	7-1/2	9-3/16	3-1/4	6-7/16	4-3/16
4-1/2	2-3/4	4-3/64	6-7/8	7-15/16	9-3/4	3-7/16	6-13/16	4-7/16
4-3/4	2-5/8	4-9/32	7-1/4	8-3/8	10-1/4	3-5/8	7-3/16	4-11/16
5	2-1/2	4-1/2	7-5/8	8-13/16	10-49/64	3-13/16	7-9/16	4-15/16
5-1/4	2-1/2	4-3/4	8	9-15/64	11-5/16	4	7-15/16	5-3/16
5-1/2	2-3/8	4-63/64	8-3/8	9-11/16	11-27/32	4-3/16	8-5/16	5-7/16
5-3/4	2-3/8	5-15/64	8-3/4	10-3/32	12-3/8	4-3/8	8-11/16	5-11/16
6	2-1/4	2-29/64	9-1/8	10-17/32	12-15/16	4-9/16	9-1/16	5-15/16

Flat-Head Machine Screw

A	.1236	.1368	.1500	.1631	.1763	.1894	.2158	.2421	.2684	.2947	.3210	.3474	.3737	.4000	.4263	.4526
B	40	36	32	32	30	30	24	20	20	18	18	16	16	16	14	14
D	.2421	.2684	.2947	.3210	.3474	.3737	.4263	.4790	5316	.5842	6368	.6895	.7421	.7421	.7948	.8474
S	.036	.039	.041	.043	.045	.048	.052	.057	.061	.066	.070	.075	.079	.084	.088	093
X	82°	82°	82°	82°	82°	82°	82°	82°	82°	82°	82°	82°	82°	82°	82°	82°

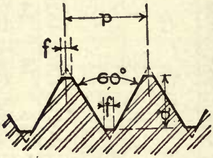
Fillister Head Machine Screws

A	.1236	.1368	.1500	.1631	.1763	.1894	.2158	.2421	.2684	.2947	.3210	.3474	.3737	.4000	.4263	.4526
B	40	36	32	32	30	30	24	20	20	18	18	16	16	16	14	14
D	.1984	2195	.2406	.2617	.2828	.3040	.3462	.3884	.4307	.4729	.5152	.5574	.5996	.6419	6841	.7264
S	.036	039	.041	.043	.045	.048	.052	.057	.061	.066	.070	.075	.079	.084	.088	.093

Round Head Machine Screw

A	.1236	.1368	.1500	.1631	.1763	1894	.2158	.2421	.2684	2947	.3210	.3474	.3737	.4000	.4263	.4526
B	40	36	32	32	30	30	24	20	20	18	18	16	16	16	14	14
D	.2270	.2512	.2754	.2996	.3238	3480	.3922	.4364	.4806	5248	.5690	.6106	.6522	.6938	.7354	7770
S	.036	.039	.041	.043	.045	.048	.052	.057	.061	.066	.070	.075	079	084	.088	.093

U. S. STANDARD SCREW THREADS.



FORMULA

$$p = \text{pitch} = \frac{1}{\text{No, threads per inch}}$$

$$d = \text{depth} = p \times .6495$$

$$f = \text{flat} = \frac{P}{8}$$

Diameter of Screw.	Threads per Inch.	Diam. at Root of Thread.	Width of Flat.
¼	20	.185	.0063
5/16	18	.2403	.0069
⅜	16	.2936	.0078
7/16	14	.3447	.0089
½	13	.4001	.0096
9/16	12	.4542	.0104
⅝	11	.5069	.0114
¾	10	.6201	.0125
⅞	9	.7307	.0139
1	8	.8376	.0156
1⅛	7	.9394	.0179
1¼	7	1.0644	.0179
1⅜	6	1.1585	.0208
1½	6	1.2835	.0208
1⅝	5½	1.3888	.0227
1¾	5	1.4902	.0250
1⅞	5	1.6152	.0250
2	4½	1.7113	.0278
2¼	4½	1.9613	.0278
2½	4	2.1752	.0313
2¾	4	2.4252	.0313
3	3½	2.6288	.0357
3¼	3½	2.8788	.0357
3½	3¼	3.1003	.0385
3¾	3	3.3170	.0417
4	3	3.5670	.0417
4¼	2⅞	3.7982	.0435
4½	2¾	4.0276	.0455
4¾	2⅝	4.2551	.0476
5	2½	4.4804	.0500
5¼	2½	4.7304	.0500
5½	2⅜	4.9530	.0526
5¾	2⅜	5.2030	.0526
6	2¼	5.4226	.0556

FOR TAPS WITH U. S. STANDARD THREADS.

Size of Tap.	No. of Thds.	Size of Drill.	Size of Tap.	No. of Thds.	Size of Drill.	Size of Tap.	No. of Thds	Size of Drill.	Size of Tap.	No. of Thds.	Size of Drill.
1/4	20	3/16 in.	11/16	11	37/64	1 1/4	7	1 5/64	2 1/8	4 1/2	1 27/32
5/16	18	1/4 in.	3/4	10	5/8	1 3/8	6	1 11/64	2 1/4	4 1/2	1 31/32
3/8	16	29/64 in.	13/16	10	11/16	1 1/2	6	1 19/64	2 3/8	4	2 1/16
7/16	14	11/32 in.	7/8	9	47/64	1 5/8	5 1/2	1 25/64	2 1/2	4	2 3/16
1/2	13	13/32 in.	15/16	9	51/64	1 3/4	5	1 1/2			
9/16	12	29/64 in.	1	8	27/32	1 7/8	5	1 5/8			
5/8	11	33/64 in.	1 1/8	7	61/64	2	4 1/2	1 23/32			

Collar-Screw

A	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4
B	40	24	20	18	16	14	13	12	11	10
D	1/8	3/16	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4
F	11/64	17/64	11/32	7/16	17/32	39/64	11/16	51/64	7/8	1-1/16
K	1/4	11/32	7/16	1/2	5/8	11/16	15/16	15/16	1	1-1/4
G	1/32	3/64	1/16	5/64	3/32	7/64	1/8	9/64	5/32	3/16

Pipe Threads

Diam.	Thds. Per In.	Diam. Drill	Diam.	Thds. Per In.	Diam. Drill
1/8	27	21/64	1-1/4	11-1/2	1-15/32
1/4	18	29/64	1-1/2	11-1/2	1-23/32
3/8	18	19/32	2	11-1/2	2- 3/16
1/2	14	23/32	2-1/2	8	2-11/16
3/4	14	15/16	3	8	3- 5/16
1	11-1/2	1-3/16	3-1/2	8	3-13/16

Standard taper of pipe threads is, 1 inch in 16, or 3/4 inch to 1 foot.

DECIMAL EQUIVALENTS

Of 8ths, 16ths, 32nds and 64ths of an inch

8ths.

1/8 = .125
1/4 = .250
3/8 = .375
1/2 = .500
5/8 = .625
3/4 = .750
7/8 = .875

16ths.

1/16 = .0625
3/16 = .1875
5/16 = .3125
7/16 = .4375
9/16 = .5625
11/16 = .6875
13/16 = .8125
15/16 = .9375

32ds.

1/32 = .03125
3/32 = .09375
5/32 = .15625
7/32 = .21875
9/32 = .28125
11/32 = .34375
13/32 = .40625
15/32 = .46875
17/32 = .53125
19/32 = .59375
21/32 = .65625
23/32 = .71875
25/32 = .78125
27/32 = .84375
29/32 = .90625
31/32 = .96875

64ths.

1/64 = .015625
3/64 = .046875
5/64 = .078125
7/64 = .109375
9/64 = .140625
11/64 = .171875
13/64 = .203125
15/64 = .234375
17/64 = .265625
19/64 = .296875
21/64 = .328125
23/64 = .359375
25/64 = .390625
27/64 = .421875
29/64 = .453125
31/64 = .484375
33/64 = .515625
35/64 = .546875
37/64 = .578125
39/64 = .609375
41/64 = .640625
43/64 = .671875
45/64 = .703125
47/64 = .734375
49/64 = .765625
51/64 = .796875
53/64 = .828125
55/64 = .859375
57/64 = .890625
59/64 = .921875
61/64 = .953125
63/64 = .984375

SIZES OF NUMBERS OF THE U. S. STANDARD GAGE.

Number of Gage.	Approximate Thickness in Fractions of an Inch.	Approximate Thickness in Decimal Parts of an Inch.	Weight per Square Foot in Ounces. Avoirdupois.	Weight per Square Foot in Pounds. Avoirdupois.
16	$\frac{1}{16}$	.0625	40	2.5
17	$\frac{9}{160}$	.05625	36	2.25
18	$\frac{1}{20}$	.05	32	2.
19	$\frac{7}{160}$	.04375	28	1.75
20	$\frac{3}{80}$	.0375	24	1.50
21	$\frac{11}{320}$	.034375	22	1.375
22	$\frac{1}{32}$	.03125	20	1.25
23	$\frac{9}{320}$	.028125	18	1.125
24	$\frac{1}{40}$	.025	16	1.
25	$\frac{7}{320}$	.021875	14	.875
26	$\frac{3}{160}$	.01875	12	.75
27	$\frac{11}{640}$	.0171875	11	.6875
28	$\frac{1}{64}$	.015625	10	.625
29	$\frac{9}{640}$	.0140625	9	.5625
30	$\frac{1}{80}$	.0125	8	.5
31	$\frac{7}{640}$	.0109375	7	.4375
32	$\frac{13}{1280}$	.01015625	6½	.40625
33	$\frac{3}{320}$	.009375	6	.375
34	$\frac{11}{1280}$	.00859375	5½	.34375
35	$\frac{5}{640}$	.0078125	5	.3125
36	$\frac{9}{1280}$	.00703125	4½	.28125
37	$\frac{17}{2560}$	.006640625	4¼	.265625
38	$\frac{1}{160}$	.00625	4	.25

DIFFERENT STANDARDS FOR WIRE GAGE.

Number of Wire Gage.	American or Brown & Sharpe.	Birmingham or Stubs' Wire.	Washburn & Moen Mfg. Co. Worcester, Mass.	Imperial Wire Gage.	Stubs' Steel Wire	U. S. Standard for Plate.	Number of Wire Gage.
000000	.....	.....	.....	.464	....	46875	000000
00000	.....	.....	.....	.432	....	4375	00000
0000	.46	.454	.3938	.400	....	.40625	0000
000	.40964	.425	.3625	.372	....	.375	000
00	.3648	.38	.3310	.348	....	.34375	00
0	.32486	.34	.3065	.324	....	.3125	0
1	.2893	.3	.2830	.300	.227	.28125	1
2	.25763	.284	.2625	.276	.219	.265625	2
3	.22942	.259	.2437	.252	.212	.25	3
4	.20431	.238	.2253	.232	.207	.234375	4
5	.18194	.22	.2070	.212	.204	.21875	5
6	.16202	.203	.1920	.192	.201	.203125	6
7	.14428	.18	.1770	.176	.199	.1875	7
8	.12849	.165	.1620	.160	.197	.171875	8
9	.11443	.148	.1483	.144	.194	.15625	9
10	.10189	.134	.1350	.128	.191	.140625	10
11	.090742	.12	.1205	.116	.188	.125	11
12	.080808	.109	.1055	.104	.185	.109375	12
13	.071961	.095	.0915	.092	.182	.09375	13
14	.064084	.083	.0800	.080	.180	.078125	14
15	.057068	.072	.0720	.072	.178	.0708125	15
16	.05082	.065	.0625	.064	.175	.0625	16
17	.045257	.058	.0540	.056	.172	.05625	17
18	.040303	.049	.0475	.048	.168	.05	18
19	.03589	.042	.0410	.040	.164	.04375	19
20	.031961	.035	.0348	.036	.161	.0375	20
21	.028462	.032	.03175	.032	.157	.034375	21
22	.025347	.028	.0286	.028	.155	.03125	22
23	.022571	.025	.0258	.024	.153	.028125	23
24	.0201	.022	.0230	.022	.151	.025	24
25	.0179	.02	.0204	.020	.148	.021875	25
26	.01594	.018	.0181	.018	.146	.01875	26
27	.014195	.016	.0173	.0164	.143	.0171875	27
28	.012641	.014	.0162	.0149	.139	.015625	28
29	.011257	.013	.0150	.0136	.134	.0140625	29
30	.010025	.012	.0140	.0124	.127	.0125	30
31	.008928	.01	.0132	.0116	.120	.0109375	31
32	.00795	.009	.0128	.0108	.115	.01015625	32
33	.00708	.008	.0118	.0100	.112	.009375	33
34	.006304	.007	.0104	.0092	.110	.00859375	34
35	.005614	.005	.0095	.0084	.108	.0078125	35
36	.005	.004	.0090	.0076	.106	.00703125	36
37	.004453	.....	.....	.0068	.103	.006640625	37
38	.003965	.....	.....	.0060	.101	.00625	38
39	.003531	.....	.....	.0052	.099	....	39
40	.003144	.....	.....	.0048	.097	....	40

GEOMETRICAL CONSTRUCTIONS

THE ELLIPSE

Definition: *An ellipse is a curve generated by the motion of a point which moves so that the sum of its distances from two fixed points is constant.* For example, in Fig. 1, the sum, x + y, of the distances from any point O on the ellipse to the two fixed points, F_1 and F_2 is constant and equal to $2a$.

Besides being considered a mathematical curve generated according to a certain law, the ellipse may be considered the curve which is cut from the surface of a right circular cone by a plane which intersects all of the elements and is oblique to the axis. Also as the orthographic projection of a circle which is oblique to the plane of projection.

The *long diameter* of the ellipse is known as the **major axis** and the *short diameter* as the **minor axis**; in analytic geometry these axes are given values of $2a$ and $2b$, Fig. 1.

Construction. The ellipse figures so prominently in drafting that it will be well to give several methods of construction, both exact and approximate.

Exact Method. (1) From the law according to which the curve is generated it has been found possible to construct the ellipse accurately as follows. With point O, Fig. 2, as a center and the axes as diameters, describe two circles. Then from O draw any number of radii of the large circle, e. g., OA, OB, OC, OD, etc. The vertices a, b, c, d, etc., of the right angles of the right triangles, Aaa_1, Bbb_1, etc., are points of the required ellipse and the curve may be traced thru these points either freehand or by means of a universal curve.

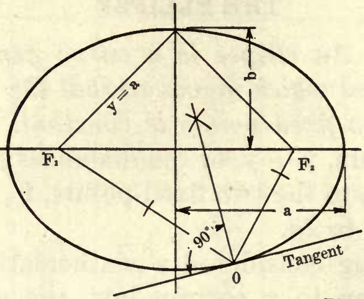


Fig. 1

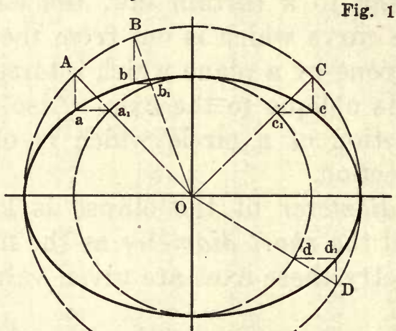


Fig. 2

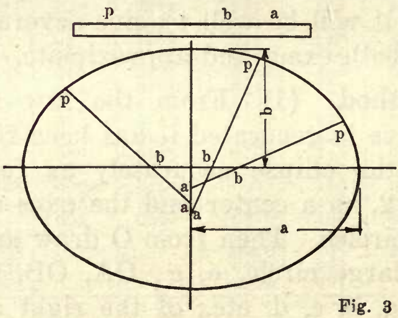


Fig. 3

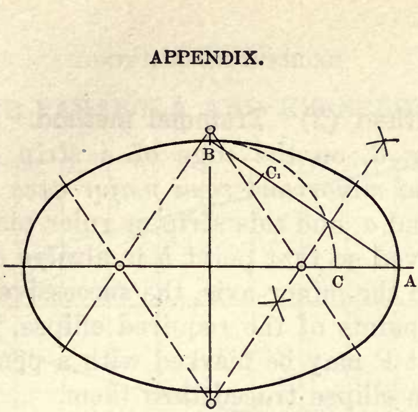


Fig. 4

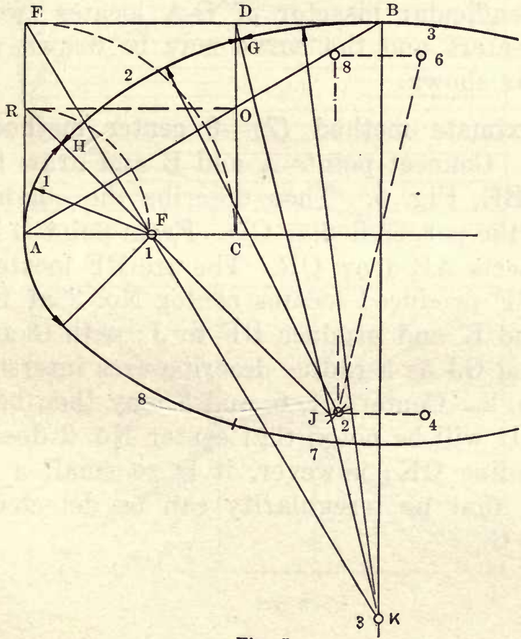


Fig. 5

Exact method (2) Trammel method. If from any point P, Fig. 3, on the edge of a strip of paper or ruler the *semi minor* and *semi major axes* be measured to points *b* and *a*, and this strip or ruler placed over the axes and moved so that point *b* is always on the major axis and *a* on the minor axis, the successive positions of point P are points of the required ellipse. These positions of point P may be marked with a pencil or needle point and the ellipse traced thru them.

Approximate method (1)—4 center method. Connect point B, Fig. 4, with point A. Then with O as a center and OB as a radius describe the arc cutting OA at C; lay off from B, on BA, the distance CA, to C_1. The perpendicular bisector of C_1A locates two of the desired centers and the curve may be drawn with the compass as shown.

Approximate method (2)—8 center method. Construction. Connect points A and B and draw the lines AE and BE, Fig. 5. Then describe the quadrant EC and erect the perpendicular CD. From point O in which CD intersects AB draw OR. The arc RF locates center No. 1. EF produced locates center No. 3 at K. Connect D and K and produce RF to J; with G and H as centers and GJ as a radius describe arcs intersecting at center No. 2. Centers, 4, 6, and 8 may then be located from 2. It will be noted that center No. 2 does not lie on the radius GK; however, it is so small a distance from GK that no irregularity can be detected in the curves at G.

THE PARABOLA AND HYPERBOLA

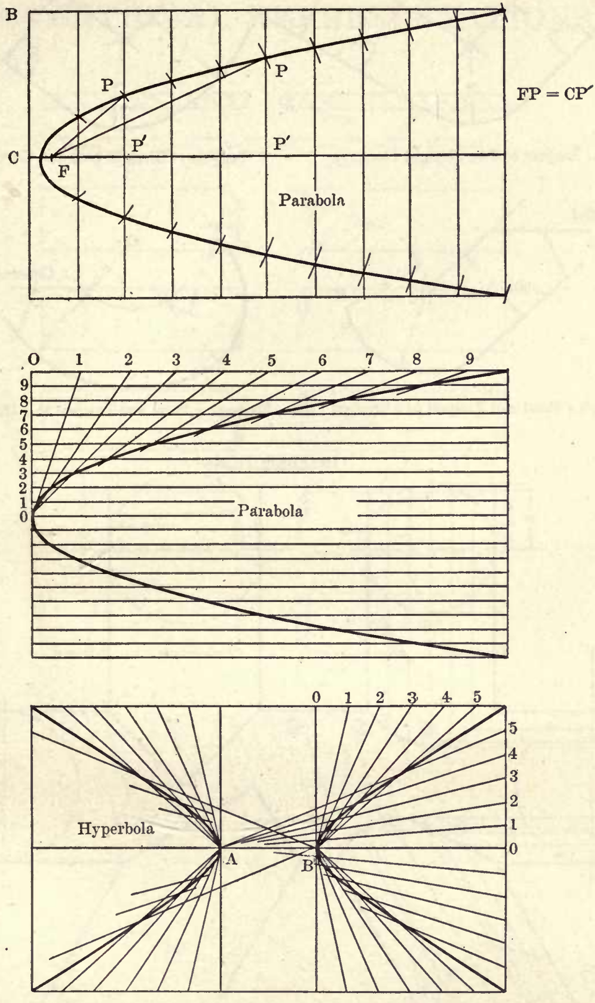
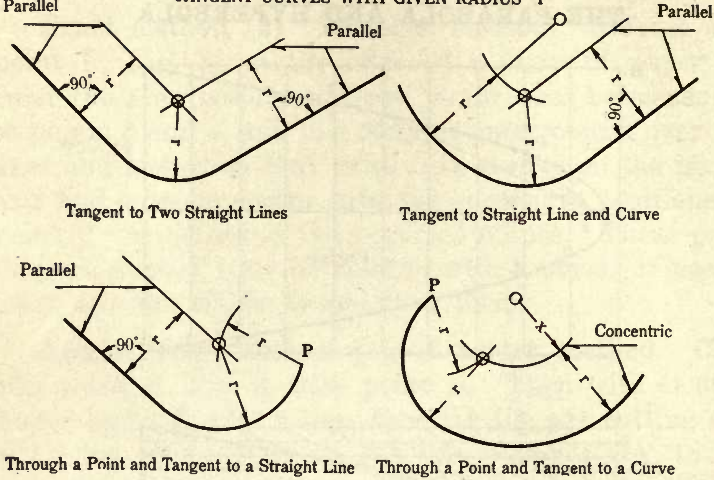


Fig. 6

TANGENT CURVES WITH GIVEN RADIUS "r"



INTERSECTIONS

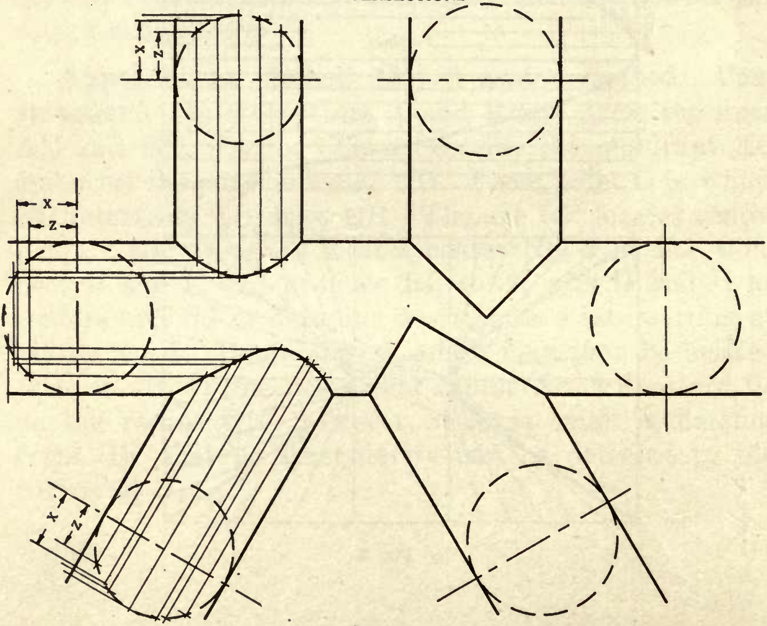


Fig. 7

CONVENTIONAL REPRESENTATIONS.

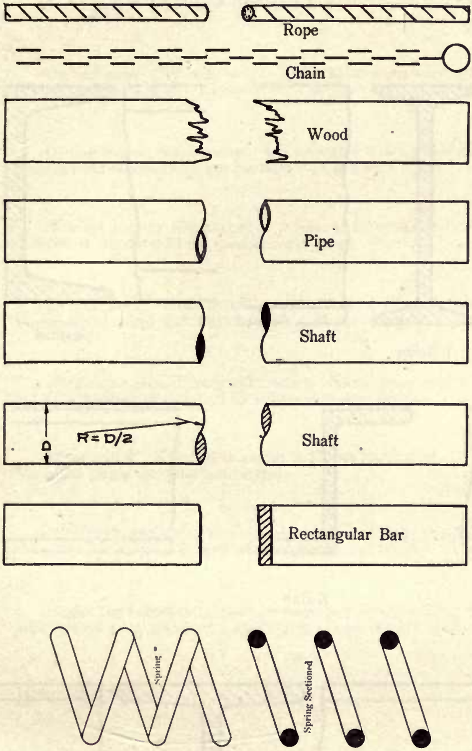


Fig. 8

CONVENTIONAL REPRESENTATIONS (Cont'd)

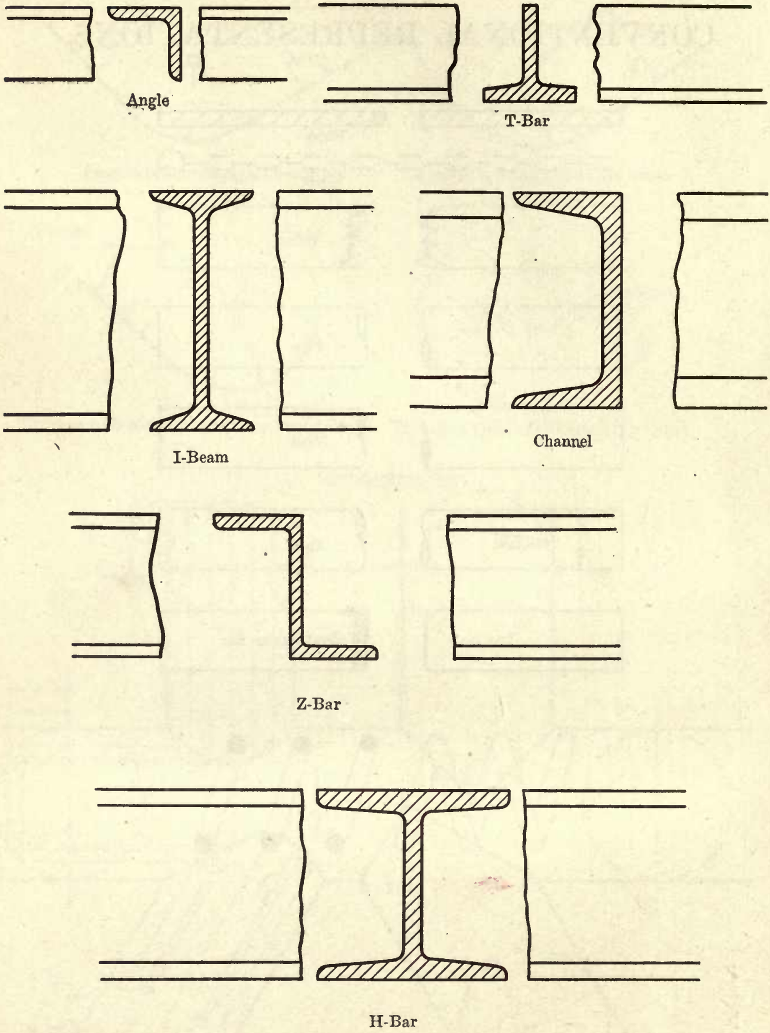
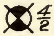


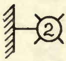
Fig. 9

STANDARD SYMBOLS ADOPTED BY THE NATIONAL CONTRACTORS' ASSOCIATION AND THE AMERICAN INSTITUTE OF ARCHITECTS.

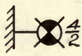
Ceiling outlet; electric only. Numeral in center indicates number of standard 16 c-p incandescent lamps.



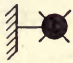
Ceiling outlet; combination. 4/2 indicates 4-16 c-p standard incandescent lamps and 2 gas burners. If gas only

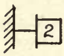


Bracket outlet; electric only. Numeral in center indicates number of standard 16 c-p incandescent lamps.



Bracket outlet; combination. 4/2 indicates 4-16 c-p standard incandescent lamps and 2 gas burners. If gas only

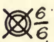




Wall or baseboard receptacle outlet. Numeral in center indicates number of standard 16 c-p incandescent lamps.

Floor outlet. Numeral in center indicates number of Standard 16 c-p incandescent lamps.

Outlet for outdoor standard or pedestal electric only. Numeral indicates number of standard 16 c-p incandescent lamps.



Outlet for outdoor standard or pedestal; combination. 6/3 indicates 6 16 c-p. standard incandescent lamps; 3 gas burners.

Drop cord outlet.

One-lamp outlet, for lamp receptacle.

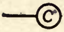
Arc lamp outlet.

Special outlet, for lighting, heating and power-current, as described in specifications.

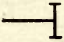
ELECTRICAL SYMBOLS (Cont'd)

	Ceiling fan outlet.
	Distribution panel.
	Junction or pull box.
	Motor outlet.
	Motor control outlet.
	Transformer.
	Main or feeder run concealed under floor.
	Main or feeder run concealed under floor above.
	Main or feeder run exposed.
	Branch circuit run concealed under floor.
	Branch circuit run concealed under floor above.
	Branch circuit run exposed.
	Pole line.
	Riser.
	Telephone outlet; private service.
	Telephone outlet; public service.
	Bell outlet.
	Buzzer outlet.
	Push button outlet. Numeral indicates number or pushes.
	Annunciator. Numeral indicates number of points.
	Speaking tube.

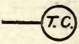
ELECTRICAL SYMBOLS (Cont'd)



Watchman clock outlet.



Watchman station outlet.

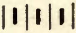


Master time clock outlet.

Secondary time clock outlet.

Door opener.

Special outlet for signal systems, as described in specifications.



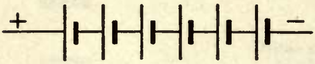
Battery outlet.

Circuit for clock, telephone, bell or other service, run under floor, concealed. Kind of service wanted ascertained by symbol to which line connects.

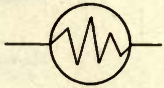
Circuit for clock, telephone, bell or other service, run under floor above, concealed. Kind of service wanted ascertained by symbol to which line connects. Meter outlet.

Meter outlet.

SYMBOLS USED IN REPRESENTING ELECTRICAL AND AUTOMOBILE CONSTRUCTION.

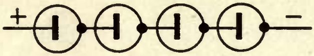


Storage Battery



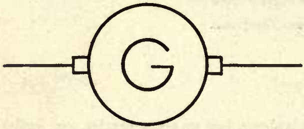
Head Light

Side Light



Dry Cells

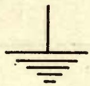
Tail, Dash or Instrument Light



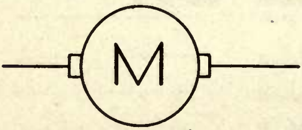
D. C. Generator Armature and Brushes

Electric Horn

Fuse



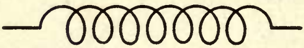
Ground



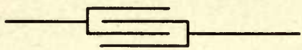
Motor Armature and Brushes

Ammeter

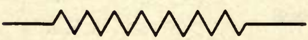
Voltmeter



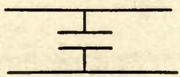
Coil—Size and Weight According to Use



Condenser

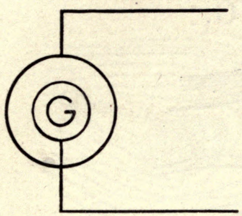


Resistance

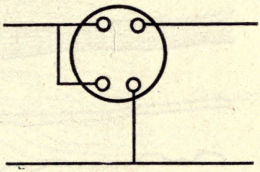


Condenser Circuit

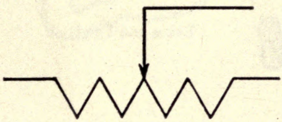
ELECTRICAL SYMBOLS (Cont'd)



A. C. Generator



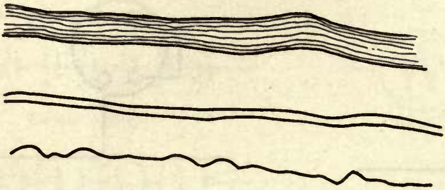
Wattmeter Circuit



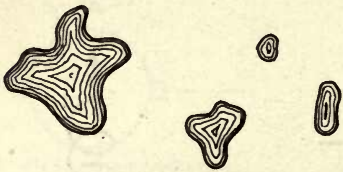
Motor Starting Circuit (Power)

Iron Cored Inductance

CONVENTIONS USED IN HYDROGRAPHICAL AND TOPOGRAPHICAL DRAWING.

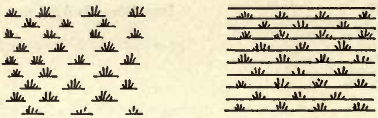


Streams



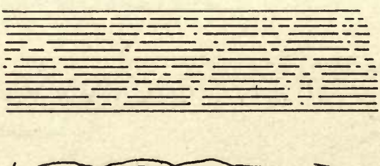
Lakes and Ponds

Falls and Rapids



Fresh Salt

Fresh and Salt Marsh



Tidal Flats

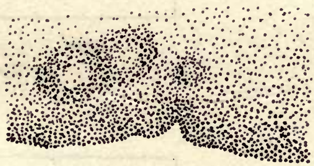
Water Lines

TOPOGRAPHICAL CONVENTIONS (Cont'd)

Contours

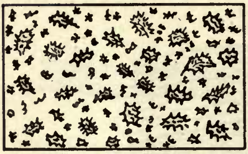
Depression Contours

Cliffs (Hachured)

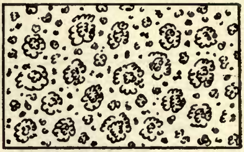


Sand

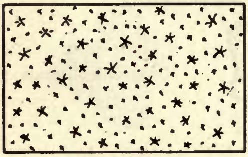
TOPOGRAPHICAL CONVENTIONS (Cont'd)



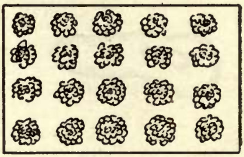
Deciduous Trees (Oak)



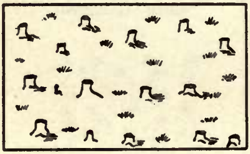
Deciduous Trees (Round Leaf)



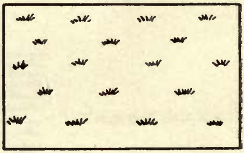
Evergreen Trees



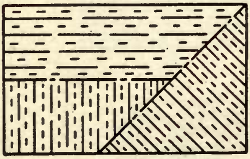
Orchard



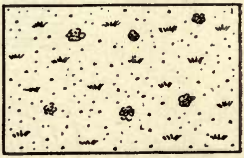
Clearing



Grass



Cultivated Land

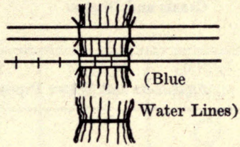


Pasture

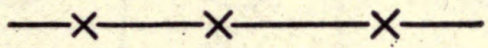
TOPOGRAPHICAL CONVENTIONS (Cont'd)

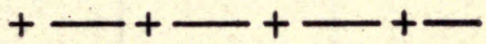
Bridges

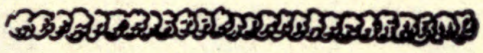
Dams

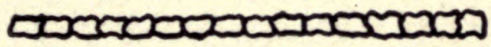


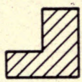
Board Fence

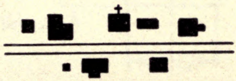
Wire Fence 

Rail Fence 

Hedge 

Stone Wall 

Buildings (Large Scale) 

Buildings (Small Scale) 

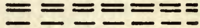
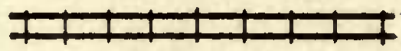
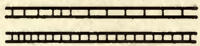
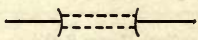
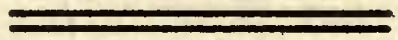
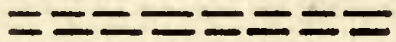
Bench Marks B. M. x 1143

Traverse Stations 

Stadia Stations 

Triangulation Stations 

TOPOGRAPHICAL CONVENTIONS (Cont'd)

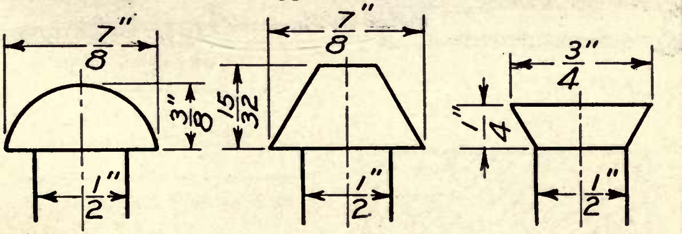
Canals and Ditches		 (Blue)
Aqueducts and Water Pipes		 (Blue)
	Single Track	
	Double Track	
Railroads	Two Lines	
	Electric	
	In Road or Street	
Tunnels		
	Metaled	
Wagon Roads		
	Poor or Private	
Paths or Trails		(Blue)
Locks		

CONVENTIONAL REPRESENTATION OF RIVETS.

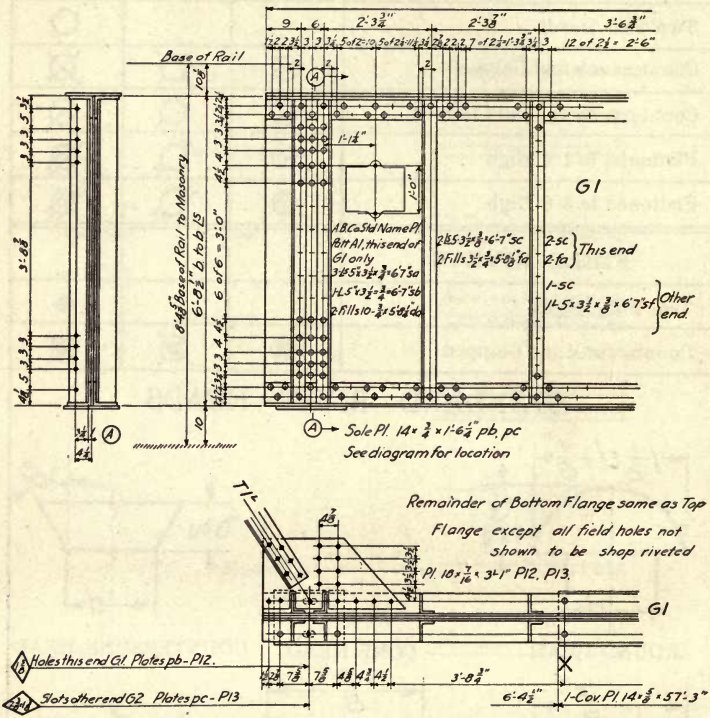
SHOP RIVETS	FAR SIDE	NEAR SIDE	BOTH SIDES
Two Full Heads			
Countersunk and Chipped			
Countersunk and not Chipped			
Flattened to 1 4 High			
Flattened to 3 8 High			
FIELD RIVETS			
Two Full Heads			
Countersunk and Chipped			

STANDARD RIVET HEADS

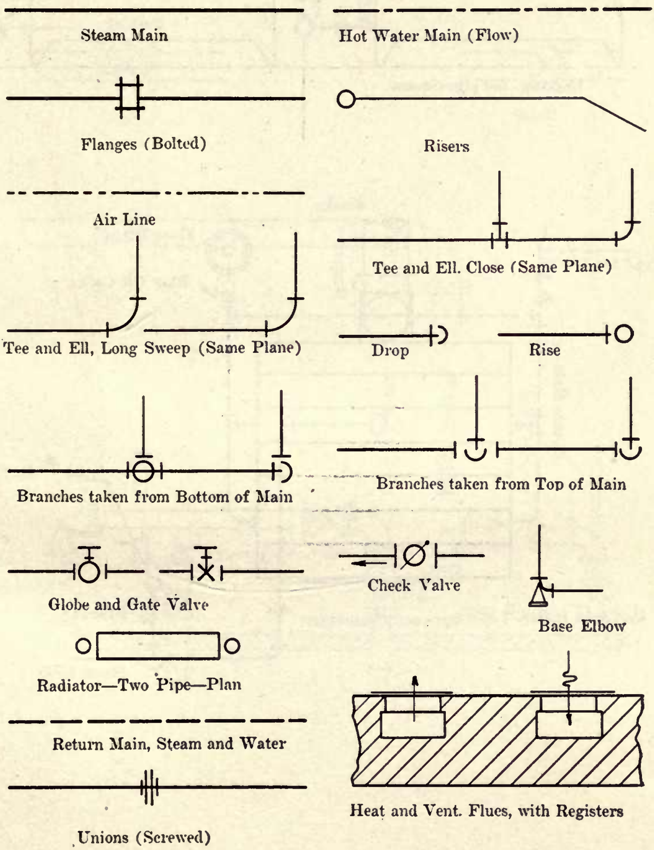
ROUND HEAD CONE HEAD COUNTERSUNK HEAD



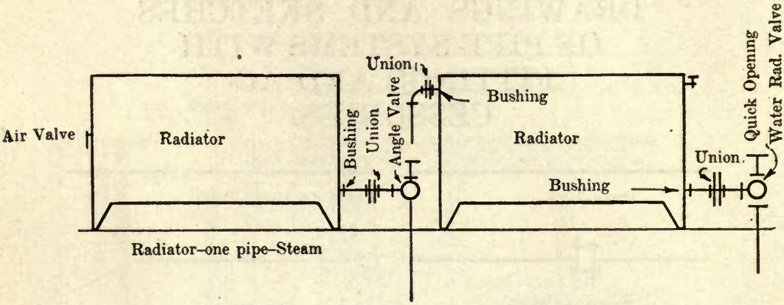
REPRESENTATION OF RIVETS (Cont'd)



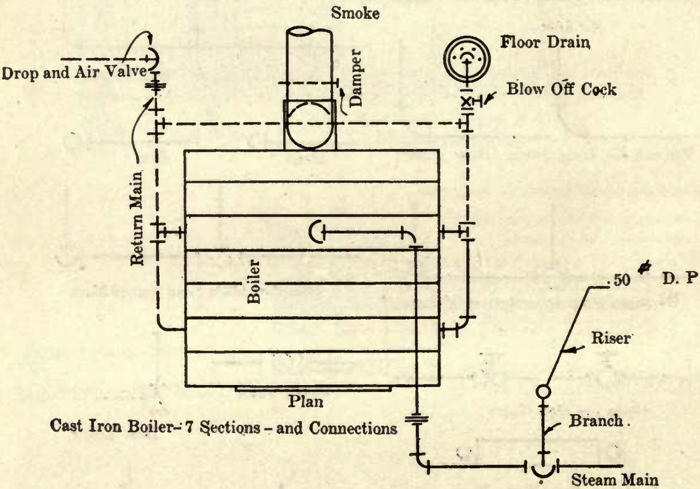
SINGLE LINE CONVENTIONAL SYMBOLS COMMONLY USED IN MAKING PRELIMINARY LAY-OUTS, SMALL SCALE DRAWINGS AND SKETCHES OF PIPE SYSTEMS WITH FITTINGS AND ACCESSORIES.



LAYOUTS OF PIPE SYSTEMS (Cont'd)

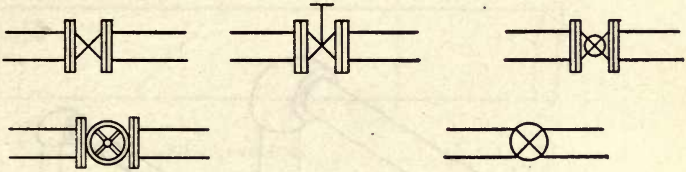


Radiator–one pipe–Steam

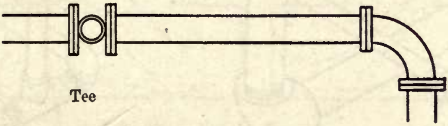


Cast Iron Boiler– 7 Sections – and Connections

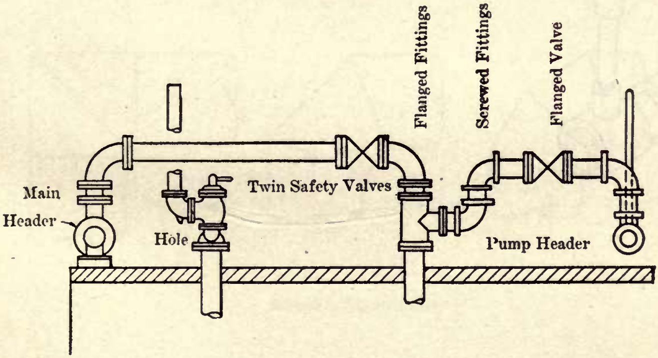
WIDELY USED SYMBOLS FOR REPRESENTING PIPE FITTINGS ON ELABORATE DRAWINGS.



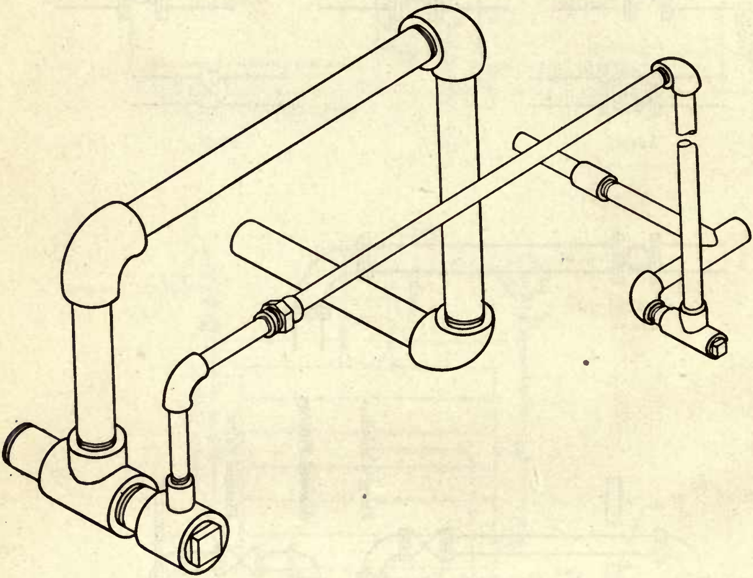
Large Small



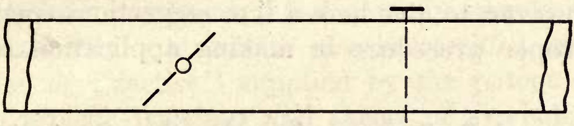
Tee Ell



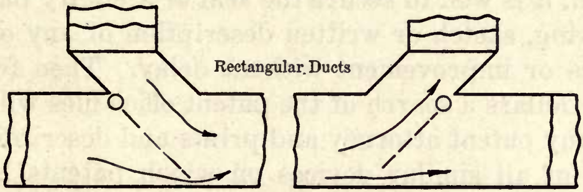
PIPE LAYOUT SHOWN IN ISOMETRIC



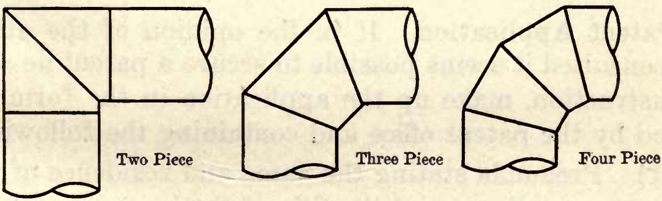
SYMBOLS REPRESENTING AIR PIPES IN HEATING AND VENTILATING.



Dampers—Elevation and Plan



Deflecting and Mixing Dampers



Elbows in Round Ducts

INFORMATION FOR INVENTORS

Note. To those interested in securing patents perhaps the best advice is that they write the Commissioner of Patents at Washington, D. C., for a copy of the "Rules of Practice in the United States Patent Office." It may be well, however, to give here a few suggestions concerning the proper procedure in making application for a patent.

Records and Preliminary Search. Since patents are occasionally contested on the point of date of conception of the idea, it is well to secure the seal of a notary public on a drawing, sketch or written description of any original device or improvement without delay. Then for a fee of ten dollars a search of the patent office files will be made by any patent attorney and prints and descriptions furnished of all similar devices on which patents have been granted. In arranging for such a preliminary search, the patent attorney should be supplied with the best possible sketch or drawing and description.

Patent Application. If in the opinion of the attorney consulted it seems possible to secure a patent he will, on instruction, make up the application in the form required by the patent office and containing the following:

(1) Preamble stating the name and residence of the applicant and the title of the invention.

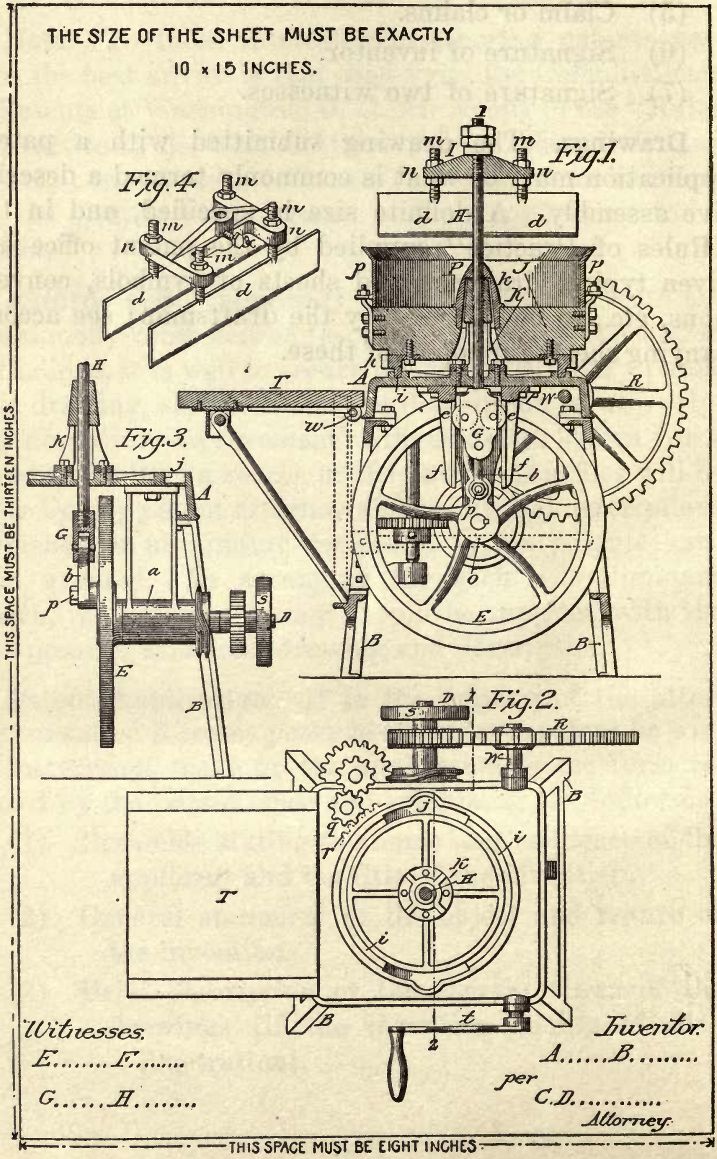
(2) General statement of the object and nature of the invention.

(3) Brief description of the several views of the drawings (if the invention admits of such illustration).

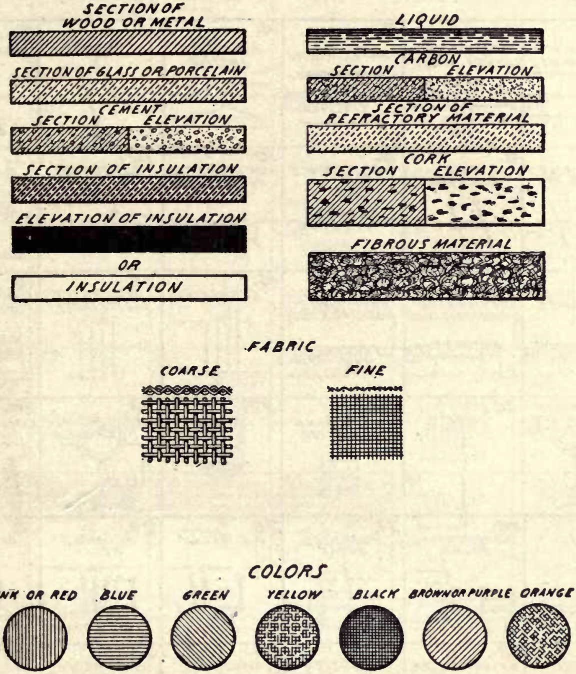
(4) Detailed description.
(5) Claim or claims.
(6) Signature of inventor.
(7) Signature of two witnesses.

Drawings. The drawing submitted with a patent application must be what is commonly termed a descriptive assembly. A definite size is specified, and in the "Rules of Practice" supplied by the patent office are given typical drawings and sheets of symbols, conventions, etc., to be followed by the draftsman; see accompanying sheets for copies of these.

TYPICAL PATENT OFFICE DRAWING



PATENT OFFICE CONVENTIONS



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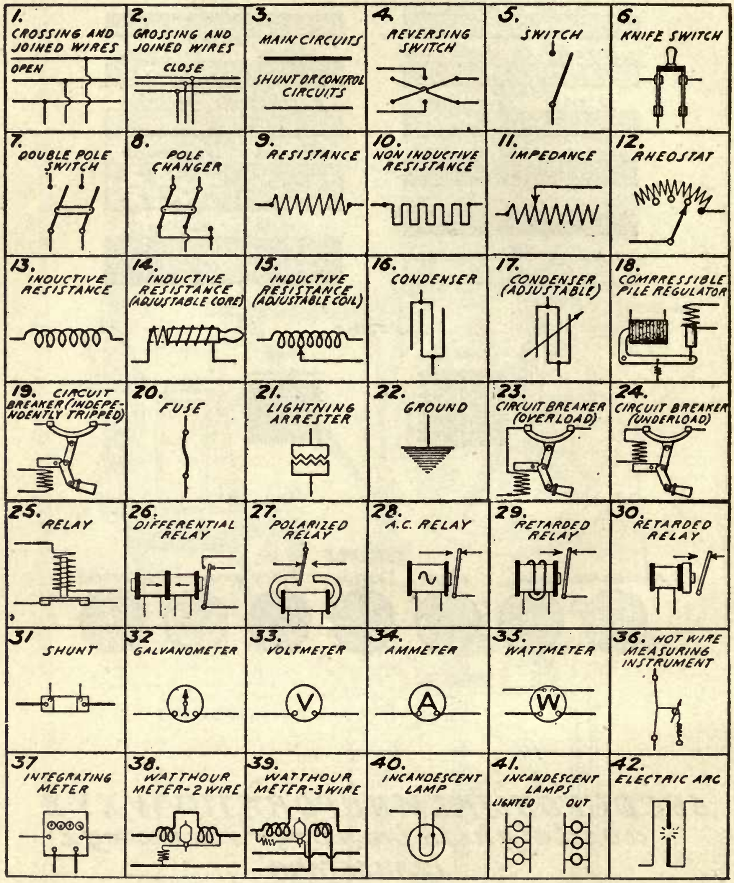
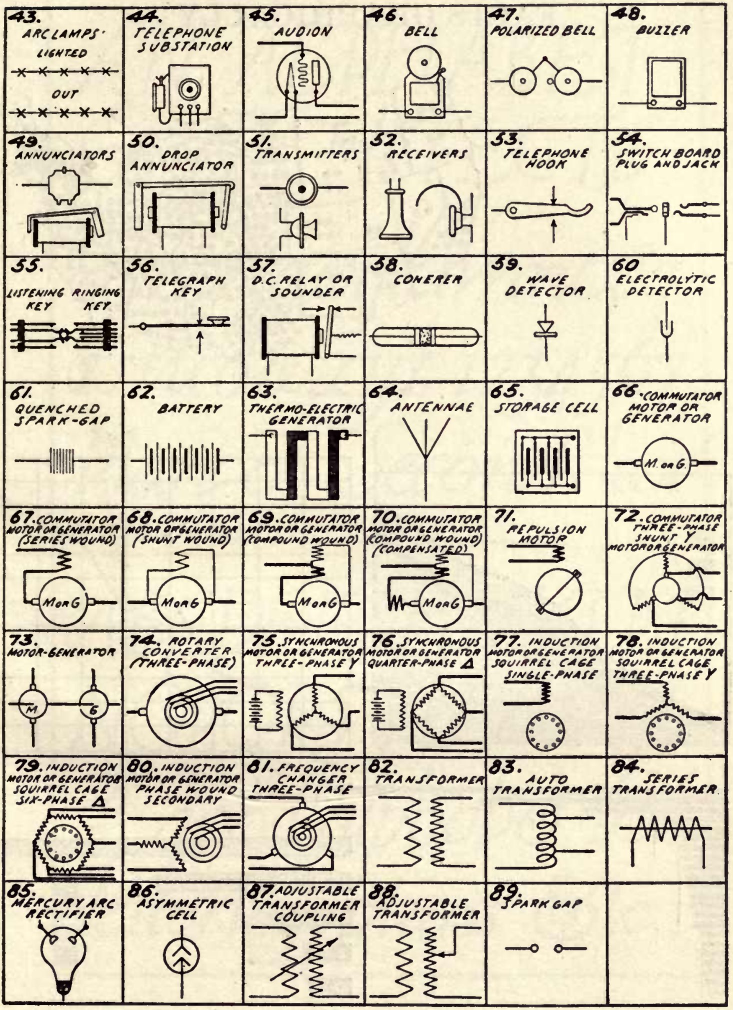
1234567890

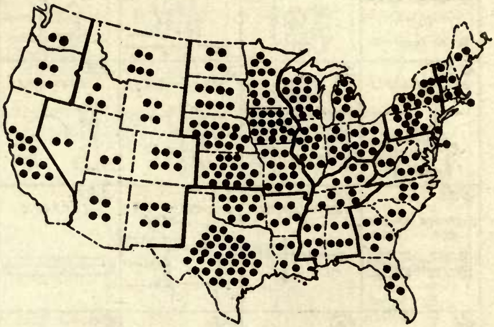
PATENT OFFICE ELECTRICAL SYMBOLS

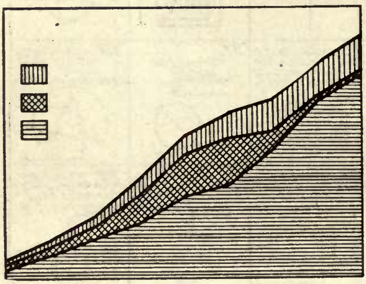


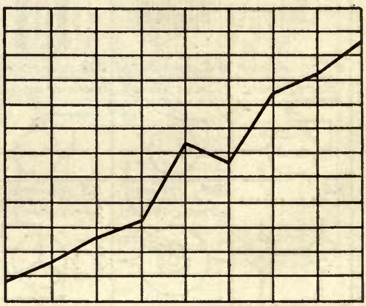
ELECTRICAL SYMBOLS (Con't)

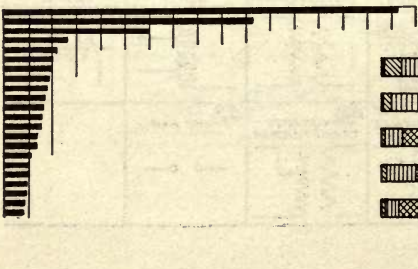


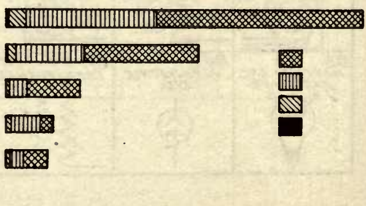
METHODS OF REPRESENTING FACTS GRAPHICALLY











ALPHABETS.

AN ALPHABET
for ARCHITECTS
abcdefghijklmnopq
rstuvwxyz 1234567
Plan of Second Floor

ABCDEFGHIJKLM
NOPQRSTUVWYZ
A good alphabet for
lettering plans &tc.

ALPHABETS (Cont'd)

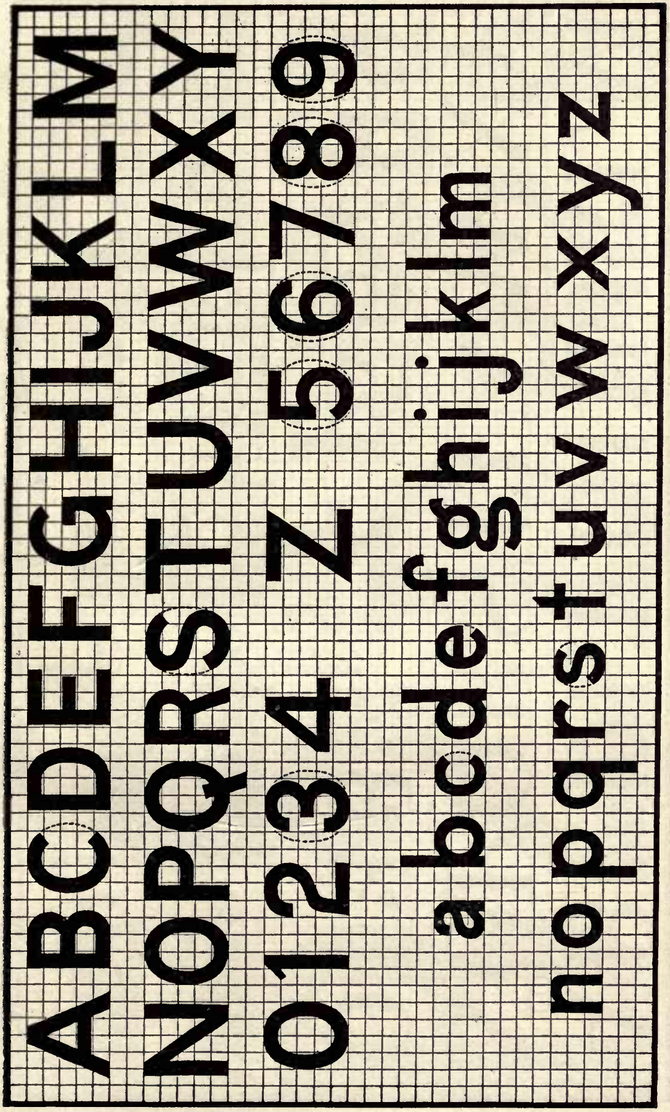
ARCHITECTURAL
LETTERS · FOR · DETAILS

Small · Letters · abcdefg
hijklmnopqrstuvwxyz
Free and yet Classic in
effect and feeling also.

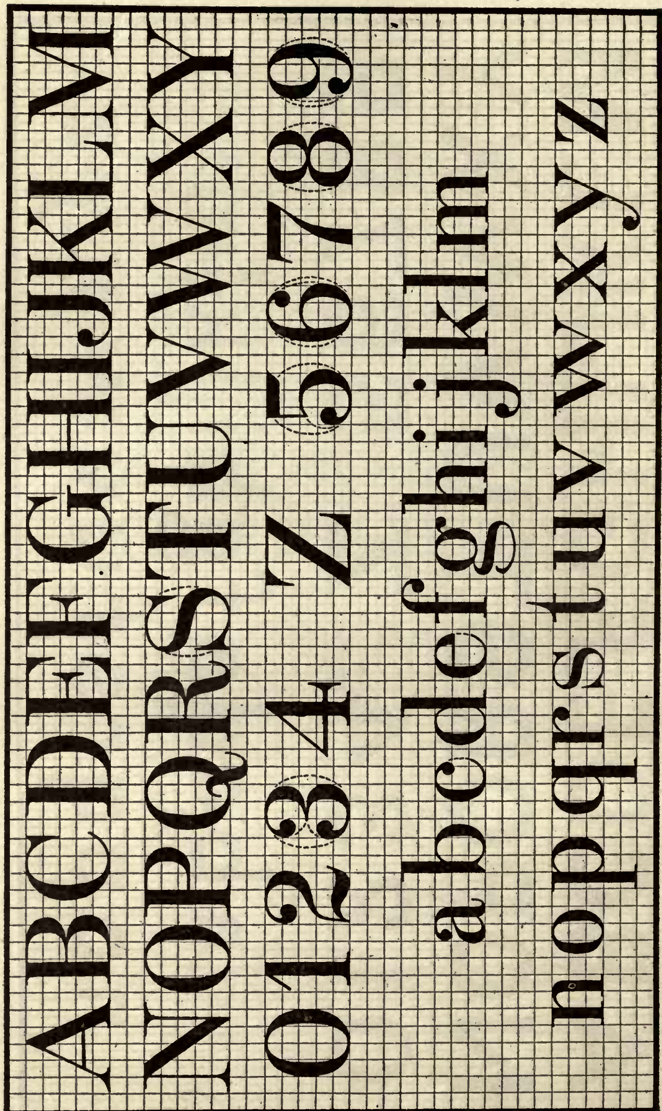
ABCDEFGHI
JKLMNOPQ
RSTUVXWYZ

Always · to be used in
Panel · form where possible

ALPHABETS (Cont'd)



ALPHABETS (Cont'd)



GUMMED LETTERS.

Made in White, Black, or Red, by The Ticket & Tablet Co. - Chicago. x - Figures only.

GUMMED LETTERS (Cont'd)

BILL OF MATERIAL (OR PARTS)

No. of Pieces	Pattern No.	Mark	Material	Name
1	A 161		C.I	Body
1	C 42		"	Stuffing Box
1	B 74		"	Gland
2	M 60		Brass	Discs
1	D 104		C.I.	Hand Wheel
1	S 16		Brass	Stem
1	L 76		C.I.	Gate
2				Stud Bolts
2				Hex. Nuts

STRAIGHT WAY VALVE
CRANE COMPANY
CHICAGO, ILLINOIS
Nov. 24, 1916 Full Size

Note: The title and bill of material need not be joined together.

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[Numbers Refer to Articles]

R.

S.

T.

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